Caseload of a farm animal veterinary teaching hospital as a form of passive surveillance with particular reference to bovine viral diarrhoea virus

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Abstract

The provision of animal health surveillance in Scotland has recently been reviewed, identifying the need to optimise surveillance delivery by making use of existing animal health data sources and more cost-efficient approaches. The Scottish Centre for Production Animal Health and Food Safety (SCPAHFS) receives uneconomic farm animal cases referred by first opinion veterinary practitioners who confirm the fitness of each animal for transport. Animals are used for teaching and receive full diagnostic work-ups, including gross post-mortem examinations; they are a potentially important source of animal health data that is already being used for teaching and research, though not yet for surveillance purposes.

With the aim to evaluate the usefulness of the SCPAHFS caseload as a source of surveillance data four studies are presented. The first study analyses and presents the demographics and referral reasons of the animals admitted to the SCPAHFS between January 2006 and December 2015. The second study focuses on the 2015 caseload and compares the diagnoses reached at the SCPAHFS with the 2014 Veterinary Investigation Diagnosis Analysis (VIDA) report. The third study collates additional information from the case files of 51 BVD persistently infected (PI) animals, with the aim to evaluate any changes in their clinical presentation that may have occurred as a consequence of the launch of the Scottish BVD eradication scheme. Finally, the fourth study presents a case study of a BVD outbreak and analyses the impact that the eradication scheme had on this particular farm.

Results of the first study show that the SCPAHFS caseload originated from Central and South-West Scotland and Northern England and is mainly represented by cattle (64%) and sheep (31%), with 5% of pigs, goats and alpacas. These proportions differ from the Scottish livestock population and the samples submitted to VIDA. The main reasons for referral of cases included digestive (31%), systemic (19%) and respiratory diseases (15%) and a proportion of cases were referred without clinical problems (8%). The second study found a clear difference between the diagnoses reached at the SCPAHFS and those included in the VIDA report. Digestive and respiratory diseases were the most common diagnoses at the SCPAHFS, both in cattle and sheep; whereas ‘diagnosis not reached’ and reproductive disease were the main categories in VIDA, followed by digestive conditions in third place. Results of the third study showed that more farmers mentioned BVD in the history of cases admitted after the start of the scheme. Animals PI with BVD virus (BVDV) admitted after the start of the scheme tended to be younger and presented with less clinical disease. In those that presented clinical signs, respiratory disease was the most common finding. In addition, no cases of mucosal disease (MD) have been diagnosed at the SCPAHFS since 2010.

Any source of passive surveillance is exposed to a degree of bias. At the SCPAHFS cases are biased towards chronic, uneconomic conditions. However, results of the presented studies indicate that the SCPAHFS caseload represents a portion of the cattle and sheep population that are not captured by the VIDA system. This could potentially act as a complimentary source of surveillance data. Additionally, the SCPAHFS caseload could also contribute with information on endemic conditions. Results of the third and fourth study confirm the success of the Scottish BVD eradication scheme, as BVD PI cattle appear to be identified and removed at earlier ages, before clinical disease, reducing their contribution to transmission of disease and the chances to develop clinical disease.

Table of contents

List of tables

List of figures

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Author's declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Anna Bruguera Sala

Abbreviations

APHA	Animal Plant and Health Agency
BDV	Border disease virus
BES	Beef Efficiency Scheme
BRD	Bovine respiratory disease
BTM	Bulk tank milk
BVA	British Veterinary Association
BVD	Bovine viral diarrhoea
BVDV	Bovine viral diarrhoea virus
BVMS	Bachelor in Veterinary Medicine and Surgery
CIS	Cattle Information Service
CN	Case number
cp	Cytopathic
CPH	County Parish Holding
CSFV	Classical swine fever virus
CT	Computed tomography
CTS	Cattle Tracing System
DSC	Disease Surveillance Centre
Ig	Immunoglobulin
MD	Mucosal disease
MDV	Mucosal disease virus
MRI	Magnetic resonance imaging
MS	Microsoft
ncp	Non-cytopathic
NFU	National Farmers Union
NFUS	National Farmers Union Scotland
OIE	World Animal Health Organisation
OPA	Ovine pulmonary adenocarcinoma
OV	Official Veterinarian
PI	Persistently infected
PM	Post-mortem
RCVS	Royal College of Veterinary Surgeons

RVC	Royal Veterinary College
SAC	Scottish Agricultural College
SAH	Small Animal Hospital
SCPAHFS	Scottish Centre for Production Animal Health and Food Safety
SRUC	Scotland's Rural College
TI	Transiently infected
TP	Total protein
TPR	Temperature, pulse, respiration
UK	United Kingdom
US	Ultrasound
USA	United States of America
VI	Veterinary Investigation
VIDA	Veterinary Investigation Diagnosis Analysis
VMDB	Veterinary Medical Database
WHO	World Health Organisation

1. Introduction

1.1. Animal Health Surveillance

1.1.1. Introduction

The term ‘surveillance’ derives from the French verb ‘surveiller’ (Hoad, 2003) and has its origins in the French Revolution, when ‘surveillance committees’ were organised to monitor the revolutionaries’ activities and act if necessary (Salman, 2003). This was an example of surveillance as we know it today; however evidence of actions related to surveillance date from as early as the 14th century, e.g. during the Black Death plague detection and control measures were applied to control the spread of the disease (Declich & Carter, 1994). Much progress has been made since the first attempts to monitor and control diseases and numerous definitions have been proposed to describe surveillance. The World Health Organisation defined public health surveillance as ‘the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice’ (World Health Organisation, 2012). In the animal health field, the World Organisation for Animal Health (OIE) defined surveillance in a very similar manner: ‘the systematic ongoing collection, collation, and analysis of information related to animal health and the timely dissemination of information so that action can be taken’ (World Organisation for Animal Health, 2015). More recently, in the 1st International Conference on Animal Health Surveillance (ICAHS) held in 2011, a group of international experts agreed on a more detailed definition of animal health surveillance: ‘the systemic measurement, collection, collation, analysis, interpretation, and timely dissemination of animal health and welfare data from defined populations. These data are essential for describing the health-hazard occurrence and to contribute to the planning, implementation, and evaluation of risk-mitigation actions’ (Hoinville et al., 2013). As stated by the definitions, surveillance involves not only the processing and analysis of data but also planned actions to be taken as a result of the interpretation of the analysis results. This differentiates surveillance from monitoring, which includes the same processes as surveillance, without the planned measures.

Animal health surveillance provides benefits at an economic, political, social and scientific level. Surveillance is essential to protect the animals' health and welfare, but also public health by preventing zoonosis and food-borne diseases. It allows demonstration of freedom from specific diseases, which is necessary to guarantee international trade. Surveillance is also the tool to detect emerging or re-emerging conditions and react against these. It provides a better understanding of the prevalence and distribution of endemic conditions and allows planning of future research and control programmes (Department for Environment Food and Rural Affairs, 2003; The Scottish Government, 2011). Emerging threats to human and animal health have been a constant in history (e.g. Bovine Spongiform Encephalopathy (BSE), Ebola, Zika virus) and there is general agreement that these will continue arising, driven by changing demographics, climate and ecosystems and the continuous increase in international commerce and animal trade (Morens et al., 2004; Baize et al., 2014; Moutou and Pastoret, 2015; Chang et al., 2016). At the same time, the science of communication and information technology is quickly progressing and this is allowing better and faster data management and analysis. In this context of continuous change and challenge, animal health surveillance needs to be constantly adapting.

The first part of this literature review will focus on the structure of surveillance systems, the different sources available to obtain animal health data, the challenges in collating and integrating these data and the organisation and delivery of surveillance in the UK and Scotland.

1.1.2. Components of surveillance systems

Surveillance systems are the practical application of surveillance (World Organisation for Animal Health, 2016a). Several authors have proposed various attributes or components that describe a surveillance system (Doherr and Audige, 2001; European Centre for Disease Prevention Control, 2014). These include: the surveillance objective, the disease/s and population under surveillance, the geographical area covered, the type of data collected, the data sources and collection methods, the collation processes, the analytical methods, the dissemination of results and the evaluation of the system. The latter is a concept that has gained importance in recent years. Evaluations of surveillance systems, in terms of

performance and economic costs, are currently not consistently performed, but these are important to ensure that systems are fit for purpose and that resources are used in the most efficient way (Drewe et al., 2013).

Regarding the objectives of surveillance systems, the most common aims are to detect the incursion of exotic, emerging and re-emerging conditions, to monitor changes in endemic conditions and to demonstrate freedom from disease (Doherr and Audige, 2001; Thrusfield, 2005). Systems may be applied at a regional, national or international level and they can focus on one or multiple conditions. Although diseases are the focus of most surveillance systems, these can also be designed to monitor other variables, e.g. risk factors for certain diseases (Declich and Carter, 1994; Doherr and Audige, 2001; Häsler et al., 2014).

1.1.2.1. Data collection

When planning or designing a surveillance system, it is necessary to establish a case definition for each disease or condition under surveillance. Case definitions allow classification of diagnoses in a uniform and clear way, to be able to count their occurrence and facilitate the analysis and interpretation of results (Declich and Carter, 1994; Weigler, 2001; European Centre for Disease Prevention Control, 2014). Definitions may consider clinical findings, laboratory test results or post-mortem (PM) lesions to define a diagnosis and they can also include definitions for confirmed and suspected cases of disease (Declich and Carter, 1994).

Animal owners, farmers, stakeholders, veterinary practitioners, diagnostic laboratories and government authorities are all involved in the collection of data for surveillance purposes. According to the way data are obtained, surveillance systems have typically been classified as ‘active’ or ‘passive’ (Hoinville et al., 2013). Active surveillance systems are those where data collection is started by the investigator or institution. In other words, the decision to investigate a disease is made at a central level. Mandatory surveillance of notifiable diseases is usually performed through active surveillance, e.g, testing for tuberculosis and brucellosis. The Scottish BVD Eradication Scheme, which in 2013 started its compulsory annual testing (The Scottish Government, 2015a), is another example of an active surveillance campaign.

In contrast, passive surveillance systems rely on the voluntary reporting of clinical cases by observers at a field level; this is often farmers and veterinarians. In the UK, the non-statutory surveillance carried out by the Animal and Plant Health Agency (APHA) and Scotland's Rural College (SRUC) laboratories is an example of a passive surveillance system. Active surveillance is usually good to estimate the prevalence of a disease in a region or to demonstrate freedom from disease, although it is associated with higher costs; whereas passive surveillance can be more cost-effective and better for detecting new conditions and changing trends in endemic diseases (Doherr and Audige, 2001; The Scottish Government, 2011). In addition to 'active' and 'passive', many terms are used to describe different and new surveillance systems (Hoinville et al., 2013). In England and Wales, the terms 'scanning' and 'targeted surveillance' are used to describe passive and active surveillance activities, respectively (Animal and Plant Health Agency, 2014b).

In the animal health field, data for surveillance purposes can be obtained from a great variety of sources. These have been reviewed by various authors (Declich and Carter, 1994; Thrusfield, 2005; The Scottish Government, 2011; Gates et al., 2015). In the UK, in addition to active surveillance campaigns for notifiable diseases, the main source of surveillance data is the testing carried out by national government-subsidised laboratories. However, farmers and veterinary practitioners may also submit samples to private centres. At the same time, private livestock health schemes are active surveillance campaigns that generate considerable amounts of animal data regarding particular diseases (Drewe et al., 2014). The potential usefulness of private laboratory and health scheme data in surveillance has been recognised (The Scottish Government, 2011), however they are not currently included in the national UK surveillance system. Data privacy and management constraints are two of the factors that complicate the collation of these sources into a national system (Velasova et al., 2015).

Not all cases seen by first opinion practitioners are submitted to laboratories. First opinion veterinarians may diagnose conditions based on obvious clinical signs (e.g. displaced abomasum) and these cases rarely get reported to national laboratories. Veterinary practices keep records of the patients seen, visits made to farms and drugs sold to clients that represent another important source of animal health data. Syndromic surveillance initiatives – a relatively new methodology that focuses on non-specific signs (e.g. clinical signs, mortality)

rather than diagnoses for early detection of new, emerging or re-emerging conditions (Dupuy et al., 2013), have looked into the potential of using clinical records in surveillance systems. In the small animal field, the SAVSNET – driven by the British Small Animal Veterinary Association (BSAVA) and the University of Liverpool (University of Liverpool, 2016), and VetCompass projects – a collaboration of the Royal Veterinary College (RVC) and the universities of Syndey, Cambridge, Sussex and Lincoln (Royal Veterinary College, 2016), are gathering data from private first opinion practices across the UK and have published various articles regarding the epidemiology and demographics of common conditions of cats, dogs and some exotic species (Jones et al., 2014; O'Neill et al., 2014b; O'Neill et al., 2016). Traditionally, apart from the few OIE-listed conditions that affect pets (e.g. rabies, leishmaniasis and leptospirosis), due to their lower economic and public health impact surveillance of companion animal diseases has been marginal compared to livestock health. Therefore, syndromic surveillance initiatives are beneficial to this field, especially in an environment where travelling pets and exotic or wild pets are becoming increasingly common (Reaser et al., 2008; Moore and Lund, 2009). Currently, neither SAVSNET nor VetCompass include clinical records from farm animal practices, although VetCompass is aiming to include equine practices in their database (Royal Veterinary College, 2015). Equine syndromic surveillance is already in application in other parts of the world (Ruple-Czerniak et al., 2014). In the United States of America (USA), the Veterinary Medical Databases (VMDB) is a system has been collecting data from veterinary college teaching hospitals since the 1960s (The Veterinary Medical Databases, 2014). Although the main focus is companion animals, the database has also provided data for epidemiological studies in cattle medicine (Constable et al., 1992; Mavangira et al., 2008). In France, New Zealand and the USA, attempts have been made to use databases to collate data from first opinion farm animal practitioners (Vourc'h et al., 2006); however, the author could not find evidence that these are still in use. Similar initiatives exist in other countries, mainly in the syndromic surveillance field. A summary of initiatives and systems that use clinical records as a source of data can be found in a review by Dupuy and others (Dupuy et al., 2013).

Drug sales and data from pharmaceutical companies can also provide information to be used for surveillance purposes. In Denmark, Sweden, Norway and Finland farm animal veterinary treatments are recorded in a national disease recording system. However poor data completeness complicated the use of these records for surveillance purposes (Mörk et al.,

2010; Lind et al., 2012). In Denmark, surveillance of antimicrobial resistance uses VETSTAT, a relational database that collates data regarding the use of drugs at a farm level (Stege et al., 2003).

Abattoirs process large numbers of carcasses every day. Live animals are examined on arrival and inspections are performed on the carcasses through processing to detect disease. The results of these inspections are already recorded in most abattoirs; however, unless there is suspicion of a notifiable condition, lesions identified during ante- and post-mortem inspections are not reported at a central level (The Scottish Government, 2011). Meat inspection has the potential to add information about conditions that may not be reported to national surveillance laboratories, especially those that are subclinical and have been missed by the farmer and veterinarian but present lesions at PM (Alton et al., 2012; Stärk et al., 2014; Vial and Reist, 2014). Condemnation rates at abattoirs do get reported and their monitoring has been shown to have potential uses in surveillance systems (Alton et al., 2012; Vial and Reist, 2014). Abattoirs receive healthy animals that are intended for human consumption, whereas fallen stock collection centres receive diseased animals that die or are euthanased on farm and that have not been submitted for PM examinations, therefore these centres could potentially identify conditions that are missed at DSC or VI centres. The main inconvenience in gathering surveillance data from fallen stock centres is the fact that PM examinations are not routinely performed in their facilities, which would require a remarkable investment of time and resources (Lovatt and Strugnell, 2013). In Europe, cattle mortality and movements have to be declared and registered. In the UK, this is done through the Cattle Tracing System (CTS) online database (British Cattle Movement Service, 2016). The final report of the review of surveillance in Scotland recommended the incorporation of CTS data into the surveillance system (The Scottish Government, 2011). Recent studies have found that monitoring mortality numbers could be useful for early detection of disease outbreaks (Perrin et al., 2012; Struchen et al., 2015; Alba et al., 2015). In addition, monitoring animal movements can help in predicting the spread of diseases and identify those areas more susceptible to outbreaks (Green and Kao, 2007).

In recent years, European legislation has driven changes in husbandry practices that may have an impact on the way diseases spread between populations, e.g. ban on individual housing of pregnant sows in 2013 (Maes et al., 2016) and removal of the milk quota in 2015

(Boere et al., 2015; Groeneveld et al., 2016). In addition, before diseases are clinically noticeable they may cause decreases in milk production or affect the animals' reproductive function. Most farmers, especially in the dairy industry, use data recording systems to monitor their animals' performance. Therefore, these can provide useful data with potential to be used for surveillance purposes (Madouasse et al., 2014; Marceau et al., 2014). In Denmark, the Danish cattle database centralises information regarding diseases, production, reproduction and other factors related to the dairy industry and has been used for surveillance purposes since 1989 (Bartlett et al., 2001). In Scotland, the Animal Health Planning System (SAHPS) and the Beef Efficency Scheme (BES) are two examples of initiatives that could provide similar data from the cattle and sheep sectors. The SAHPS is a web-based system used mainly by sheep and beef farmers. It records production and disease data and allows comparison of performance between farms (Scotland's Rural College, 2016a). The BES is a five-year project that aims to improve the economic and environmental efficiency of beef suckler herds (The Scottish Government, 2016a). Farmers that take part in the scheme are required to record calving data, including the calving ease, the calf vigour and calf mortality and, as an incentive, they are offered a payment of £32 per calf (The Scottish Government, 2016c). In addition to paper records, these data have to be entered into a database designed for the scheme. This database is hosted on the ScotEID webpage, which also hosts the Scottish BVD Eradication Scheme database created in 2013 (ScotEID, 2016). In the dairy industry, the Cattle Information System (CIS) is another web based recording system that collates performance and disease data and produces a wide variety of reports for farmers and veterinarians (Cattle Information Service, 2016). The fact that data like those generated by the SAHPS, BES and CIS are already available in electronic format should be favourable for them being useful to evaluate the situation and monitor changes in the sector.

1.1.2.2. Data collation

Data for surveillance purposes can be obtained from many sources: however, various factors complicate the collation of these data into a common surveillance system. One of the main constraints is that, in most cases, different institutions and providers use different terminology and diagnoses that are often not based on pre-established case definitions (Stark and Nevel, 2009). Unifying the language and terms is key to allow communication and

transfer of data between sources. Human medicine is years ahead of veterinary in the use of coded terminology and diagnoses. The largest terminology catalogue in human health is the Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT), which has been in use for over 40 years. The SNOMED CT catalogue also includes veterinary terms and is used by the VMDB (The Veterinary Medical Databases, 2014). Examples of standardised terminology specific to veterinary medicine are scarce. In the UK, the Veterinary Nomenclature (VeNom) codes were initially derived from SNOMED CT with the aim to create a terminology that was more accessible to veterinary practitioners (VeNom Coding Group, 2009). These are being used by the VetCompass project (O'Neill et al., 2014a). However, VeNom does not include pathologies that are specific to farm animals such as abomasal displacements. There are currently no standardised coding systems specific to production animals. The VIDA system diagnostic codes were based on the terminology developed by the University of Michigan and the National Cancer Institute in America (Hugh-Jones et al., 1969) and these have been regularly reviewed and updated since the database was created (Gibbens et al., 2008).

Another constraint to the collation of data from various sources is differences between the data recording methods used by different providers. Although the use of data management software is increasing, different systems are not inter-connected and some providers still record data in paper format (Stark and Nevel, 2009). In addition, although systems like the CIS or SAHPS are web based and all the users record data in the same platform, farmers may make different uses of the system and record data in different ways, e.g. some dairy farmers may not record subclinical mastitis in the CIS and other may record subclinical cows with high somatic cell counts as cases of clinical mastitis. In the UK, a study found that the potential usefulness of various health schemes and production recording systems for surveillance purposes was affected by remarkable differences between the data management systems used (Velasova et al., 2015). In 2015 the Agriculture & Horticulture Development Board (AHDB) launched the Data Hub Project with the aim to facilitate data exchange between the Government and private databases, initially focusing on animal diseases, but with plans to expand to other types of production data (Agriculture & Horticulture Development Board, 2015). The Rapid Analysis and Detection of Animal-related Risks (RADAR) database is an example of a system that collates surveillance data from multiple sources in the UK. These include data from the Cattle Tracing System (CTS), the APHA VI

centres results and the brucellosis and Salmonella testing campaigns (Lysons et al., 2007). However, information about access through this system and the currency of the data are difficult to find.

1.1.2.3. Bias in surveillance data

In addition to the obstacles to collate data from various sources, bias is a common factor affecting surveillance data quality. Bias is defined as "an error in the conception and design of a study — or in the collection, analysis, interpretation, reporting, publication, or review of data — leading to results or conclusions that are systematically (as opposed to randomly) different from truth" (Porta, 2008). Any surveillance system is exposed to a degree of bias. Although most active surveillance systems depart from planned data collections, based on sample calculations that should guarantee that the estimates are truly representative of the general population (Salman, 2003), sampling errors or bias still occur in some cases. For example, risk based surveillance efforts are purposely skewed towards groups of animals that are thought to be more likely to suffer certain diseases (Thrusfield, 2005). In addition, test inaccuracies due to low sensitivity and specificity can also lead to inaccurate results (Haut and Provost, 2011). However, the nature of data gathered for passive surveillance is always associated with a higher degree of bias. Passive systems rely on the willingness of farmers and first opinion veterinarians to submit cases or samples and this can be affected by a multitude of factors, leading to selection bias (Robinson et al., 2012). Underreporting is a common problem in passive surveillance and incentives and subsidised testing are aimed at increasing the submission rates to national surveillance laboratories (Zurbrigg and Van den Borre, 2013; Struchen et al., 2015). Disease awareness also has an impact on submission of cases to surveillance systems. Severe diseases, those that have higher mortality rates, that affect more animals or unknown conditions, are more likely to be reported; whereas those endemic, common conditions that can cause less apparent losses or that may be diagnosed by the first opinion veterinarian (e.g. displaced abomasum, lameness, ringworm) are usually underreported (Declich and Carter, 1994; Watson et al., 2008; Animal and Plant Health Agency, 2014d). The value of the animal and the distance to the laboratory or referral centre are other factors that can affect submission rates (Watson et al., 2008; Bartlett et al., 2010). It has been found that farmers participating in health schemes are more likely to submit

samples to DSC or VI centres, since they usually have a keen interest in knowing what diseases are affecting their herds or flocks (Watson et al., 2008). Data obtained from certain sources are also biased *per se*, for example, animals submitted to abattoirs represent a healthy sample of the population, whereas fallen stock collection services receive diseased, uneconomic individuals. Veterinary hospitals are exposed to referral bias, due to the fact that certain conditions are dealt with by first opinion practitioners and they receive those that need specialised care (Bartlett et al., 2010). Misclassification of diagnoses can also affect surveillance data, when different diagnostic methods are used and especially when no case definitions are established, since two clinicians may reach different conclusions based on a series of clinical signs. In addition, disease prevalence and incidence can usually only be calculated with data collected through active methodologies, since they provide details about the sampled population (Doherr and Audige, 2001), and these are rarely available in passive surveillance datasets.

1.1.2.4. Integration of results

Data analysis is the essential process that allows interpretation of surveillance data. Depending on the system and type of data collected, various analytical methods can be used. These include basic statistics (statistical tests and equations), regression models including time series, spatial epidemiology and simulation modelling, among others (Höhle et al., 2009; Rodríguez-Prieto et al., 2014). To detect changes in disease trends, the analysis of surveillance data usually involves comparing the results obtained with previous observations made in the same region or between neighbouring areas (Declich and Carter, 1994). As an example, in the case of the VIDA database, quarterly data are compared to the previous quarter and to the mean in the same quarter of previous years (Gibbens et al., 2008)

1.1.2.5. Communication of results

After the analysis of surveillance data, sharing its results is key to fulfil the ultimate aim of a surveillance system: to produce information that helps institutions, stakeholders, veterinary practitioners and farmers make decisions regarding the prevention and control of animal

disease (Department for Environment Food and Rural Affairs, 2003). In passive surveillance systems, where the reporting by farmers and veterinarians is essential for data collection, communication and feedback helps raise awareness and improves the engagement and participation in the system (Robinson et al., 2012).

Surveillance results need to be presented in a clear way that helps the reader to understand and interpret the data. Reports should include tables, graphs and/or figures and be accompanied by text interpreting the results. However, the format of the report may vary based on the audience it is aimed at, e.g. general public, farmers, veterinarians or government members. Nowadays, most reports are shared via email or made available online, although in some cases data are still published in paper format. The frequency of reporting usually varies from monthly or quarterly to annual reports (Declich and Carter, 1994).

The OIE collates results from surveillance of listed conditions around the world. These are used to present the worldwide prevalence and distribution of these conditions in maps and reports through the World Animal Health Information Database (WAHID) interface (World Organisation for Animal Health, 2013). This is an interactive webpage that includes weekly reports for new and ongoing disease outbreaks at the country level. Maps for outbreaks and the country status regarding a specific disease are also available. However, data are only available grouped by six-month periods, they are often not up-to-date and information is missing for many countries. In the UK, an annual report is produced from the VIDA database (Animal and Plant Health Agency, 2015c), which can be freely accessed through the APHA website. The report presents the monthly diagnoses reached at the APHA VIC and SRUC DSC during that year and the yearly diagnoses for the last seven years. However, it is usually published in September/October of the following year, which limits the value it has. These are presented in a table format and some accompanying graphs and figures in an additional document (Animal and Plant Health Agency, 2014d); however, there is no text accompanying the data, which makes the result interpretation more difficult for the public. However, the report includes the total number of samples received per year, which allows the public to make their own calculations, and additional data can be retrieved from VIDA by contacting the AHPA. In addition to the annual VIDA report, in England and Wales, the APHA publishes a monthly report that highlights the most commonly reported or interesting conditions diagnosed at their VIC (Animal and Plant Health Agency, 2015a), which

eventually includes graphs. The same report is published in the Veterinary Record (Animal and Plant Health Agency, 2015b). In January 2016, after changes were made to the organisation of surveillance delivery in England and Wales (see section 1.1.3.2.), the report's format was updated to incorporate surveillance information obtained by sources outside the Government (Animal and Plant Health Agency, 2016). The new report also includes a section on international disease monitoring and a section dedicated to topics raised by the Veterinary Risk Group (VRG), a cross-government group that was created in 2009 in response to the need to include emerging threats in the existing UK surveillance system (Del Rio Vilas et al., 2013; Anon, 2016). A monthly report produced by the Scottish Agricultural College (SAC) Consulting Veterinary Services aimed at veterinary practitioners can be found in the Veterinary Record (SAC Consulting Veterinary Services, 2015) and in the SRUC's website (Scotland's Rural College, 2016b). The format is very similar to the old APHA's report and only includes descriptions of cases. The total numbers and data regarding all the pathologies diagnosed at the DSC are not usually provided. The SAC also publishes a twice-yearly surveillance newsletter aimed at livestock keepers which includes short summaries on endemic and emerging conditions, accompanied by pictures that may help to improve reporting (Scotland's Rural College, 2016c). However, an equivalent of the VIDA report with conditions diagnosed in Scotland is not available. In Northern Ireland, regular summaries are also published in the Veterinary Record (Agri-Food and Biosciences Institute, 2015); however, the results from passive surveillance are not reported into the VIDA system but published in the All Ireland annual report (Department of Agriculture Food and the Marine and Agri-Food and Biosciences Institute, 2015), which also includes results from surveillance activities in the Republic of Ireland. In this case, although the report is annual, it is a longer document that presents the results of surveillance in graphs and figures accompanied by written summaries and covers several conditions, including anthelmintic and antimicrobial resistance. The report includes pictures of PM findings, which may be useful to help veterinary practitioners in identifying pathologies when performing field PM examinations. In Australia, the National Animal Health Information System (NAHIS) which integrates data from multiple surveillance programmes in the country, publishes extensive quarterly and annual reports that present statistics accompanied by figures, graphs, maps and provides a good interpretation of the results (Animal Health Australia, 2016b; Animal Health Australia, 2016a). In addition to official reports published by subsidised laboratories, scientific articles in peer-reviewed journals are another common way of reporting

surveillance data. An example of these are the BVD prevalence studies performed before the start of the Scottish BVD Eradication Scheme (Brülisauer et al., 2010; Humphry et al., 2012)

1.1.3. The delivery of animal health surveillance

1.1.3.1. International examples

The principles of surveillance are the same around the world; however, different countries may adopt different approaches to organise their surveillance systems. One of the main differences is how surveillance is funded. The majority of surveillance systems across European countries are publicly funded; however, some base their surveillance only on private systems (Häsler et al., 2014). The latter is the case for Denmark, where it was decided that, due to the small amount of imports the risk of introducing new diseases was very low and it did not justify a government funded laboratory (The Scottish Government, 2011). The organisation of laboratories and institutions performing surveillance activities also varies across the world. In the USA and Canada, surveillance for non-notifiable conditions relies on state and provincial organisations, but a national network coordinates the surveillance activities carried out by the different centres (Kloeze et al., 2010; United States Department of Agriculture, 2016). In Finland, four government-funded laboratories are localised in the areas with highest livestock density (The Scottish Government, 2011), whereas in The Netherlands only one laboratory is responsible for the testing of samples that generate surveillance data. The latter is located in the geographical centre of the country, which has been shown to not affect case submission rates. Animal health surveillance there is supplemented by a telephone helpdesk that offers advice to veterinarians and may start follow-up investigations when needed (GD Animal Health, 2014). This system allowed the early detection of Bluetongue virus serotype 8 and Schmallenberg virus (van Wuijckhuise et al., 2006; Elbers et al., 2012). In addition, The Netherlands also collects data from many other sources including production and husbandry data and abattoirs (GD Animal Health, 2014). This is also the case in the Scandinavian countries, where data regarding drug usage is used especially for the monitoring of antimicrobial resistance (Stege et al., 2003).

1.1.3.2. The United Kingdom system

Examples of how surveillance is organised in the UK have already been given in previous sections. To finish with the surveillance part of this literature review, an overview of the delivery of surveillance in the UK and Scotland is given in this section, with emphasis on the recent reviews and changes in its organisation.

In addition to active or targeted surveillance campaigns for notifiable diseases, the main source of surveillance in the UK is the publicly subsidised testing performed at the APHA VI centres in England and Wales, the SRUC DSC in Scotland and the AFBI laboratories in Northern Ireland. Private laboratories and livestock health schemes represent additional surveillance initiatives, although due to privacy and commercial reasons, very few data are publicly available (Drewe et al., 2014). In 2012 it was calculated that approximately 14% of cattle herds were included in the Cattle Health Certification Standards (CHeCS) that regulates health schemes across the UK and the Republic of Ireland (Brigstocke, 2012). These include important diseases like BVD and Johne's disease and represent a missed opportunity to benefit from information regarding the prevalence of these conditions in the UK. Overall, cattle are the focus of most surveillance activities in the UK, involving nearly 94% of the public and private surveillance expenditure. By contrast, sheep represent up to 70% of the British livestock population and only receive 2% of the surveillance funds (Drewe et al., 2014; The Scottish Government, 2016b).

The diagnoses reached at the VI centres and DSC are collated in the VIDA database. The VIDA system was developed in 1967 (Hugh-Jones et al., 1969) and re-designed in 1973 (Hall et al., 1980). This was the first veterinary diagnostic centralised recording system in the UK. The VIDA codes were adapted from the Veterinary Medical Data Processing Scheme (VMDP) created by the US National Cancer Institute and have been periodically reviewed since then (Hugh-Jones et al., 1969; Hall et al., 1980). The individual diagnoses are grouped under nine body system groups which have been in use since VIDA was developed (Hugh-Jones et al., 1969). Initially, information was stored using card tabulators, but these were replaced by computers in the early 70s. Data were analysed annually. The main disadvantage of the VIDA database was that a category or detection system was not included for unknown emerging conditions. Therefore, after the bovine spongiform

encephalopathy (BSE) crisis, the system was reviewed in 1999. A new database called FarmFile was created to record additional information (Gibbens et al., 2008). Since 2004 data are analysed every four months and syndromes (diseases grouped by systems) and 'diagnosis not reached' (DNR) cases are analysed to detect any clusters that may suggest emergence of new or re-emergence of existing conditions (Gibbens et al., 2008). Bovine neonatal pancytopenia ('bleeding calf syndrome') and Schmallenberg virus are two examples of emerging diseases whose incursions in the UK were first detected by the APHA network of VI centres (Veterinary Laboratories Agency, 2009; Anon, 2012). During the first years of the database, about 150,000 samples were processed each year (Hall et al., 1980). Between 43,000 and 63,000 samples have been submitted to the database over the last eight years, with a progressive decrease in numbers since 2012 (Animal and Plant Health Agency, 2015c).

The first national laboratories in the UK were established in 1922 and since then the delivery of surveillance and the organisation of the laboratories have undergone many reviews (Bradley, 2000; The Scottish Government, 2011). After the BSE and FMD crises, the whole UK surveillance strategy was reconsidered in 2003 (Department for Environment Food and Rural Affairs, 2003). As a consequence, both the delivery of surveillance in England and Wales and Scotland were reviewed in 2012 and 2011 respectively (The Scottish Government, 2011; Surveillance Advisory Group, 2012). After the recommendations made by both reports, changes to the organisation of surveillance are still being debated. The need for more cost-effective approaches to veterinary surveillance was identified in both reviews. In England and Wales the APHA funding has been reduced from £10.2 to 7.2 million between 2010 and 2015 and in 2014 the first changes were applied to the delivery of PM examinations, with the closure of eight PM facilities. The provision of PM examinations was then supplemented by the RVC, the University of Bristol, the University of Surrey and the SRUC in North East England (Animal Health and Veterinary Laboratories Agency, 2013). A triage of samples has been added to the submission process and only those samples with potential use as surveillance material receive subsidised testing (University of Surrey, 2015) and a carcass collection service was introduced for those farms located more than one hour away from the PM examination facilities (Animal and Plant Health Agency, 2014a). In Scotland, an outcome of the 2011 review in Scotland was the creation of a 'Strategic Management Board' which was established in 2012 and is responsible for advising the

Scottish Government in the field of animal health surveillance. The review also recommended the closure of SRUC DSC, the centralisation of the laboratory services into one facility and the incorporation of existing animal health data streams to the current surveillance system (e.g. abattoir and CTS data) (The Scottish Government, 2011). The closure of the Inverness and Ayr DSC was discussed. A consultation process took place in which it was suggested that the Ayr DSC services could have been transferred to the School of Veterinary Medicine of the University of Glasgow. However, after the consultation with farmers, veterinarians and stakeholders it was decided to maintain both centres with some reorganisation.

The Scottish Centre for Production Animal Health and Food Safety (SCPAHFS) of the School of Veterinary Medicine of the University of Glasgow receives uneconomic cases donated by farmers and veterinarians in Scotland and Northern England. Animals receive full diagnostic work ups, including gross PM examinations and therefore represent an important source of animal health data. This data stream could potentially contribute to the existing surveillance system in Scotland and one of the aims of this thesis is to assess this possibility.

1.2. Bovine Viral Diarrhoea Virus

1.2.1. Introduction

In 1946, 'an acute, infectious and contagious disease of cattle' which caused 'gastroenteritis with severe diarrhoea' was described for the first time in the United States of America (USA) (Olafson et al., 1946) and Canada (Childs, 1946). The disease was later named Bovine Viral Diarrhoea (BVD) (Olafson and Rickard, 1947). Over the past 70 years several research streams have continuously focused on BVD, which has been recognised as a disease that has a large impact on cattle productivity (Bennett et al., 1999; Gunn et al., 2004; Houe, 2003). The disease has been widely reviewed (Lanyon et al., 2014; Grooms, 2004; Baker, 1995; Brodersen, 2014; Campbell, 2004), new studies are published every year and, although the complex pathogenesis of BVD virus (BVDV) is not completely understood yet, many countries have applied successful BVD eradication programmes (Valle et al., 2005; Presi et al., 2011; Synge et al., 1999; Bitsch et al., 2000; Presi and Heim, 2010). In Scotland, a BVD eradication scheme was launched in 2010. By 2015 it was calculated that only 12% of the herds were still exposed to BVDV (The Scottish Government, 2016d). The Scottish Centre for Production Animal Health and Food Safety (SCPAHFS) has admitted animals persistently infected (PI) with BVDV since before the start of the Scottish eradication scheme. Currently, BVDV PI animals are still being admitted. Chapter 5 of this thesis analyses the evolution of the clinical presentation of PI animals at the SCPAHFS over this period and Chapter 6 presents a case study of an outbreak at a Scottish farm during the Eradication Scheme. Therefore, general aspects of the disease will be reviewed in this section, with focus on its clinical presentation, control and eradication and the current situation in Scotland.

1.2.2. Aetiology

Bovine Viral Diarrhoea is caused by a virus of the family *Flaviviridae*, genus *Pestivirus.* Virions of the genus *Pestivirus* are small (40-60 nm in diameter), spherical, have a single strand of RNA and present a lipid envelope that makes them sensitive to most common

disinfectants (King et al., 2011). The genus *Pestivirus* includes four species: Classical Swine Fever Virus (CSFV), Border Disease Virus (BDV), Bovine Viral Diarrhoea Virus 1 (BVDV-1) and Bovine Viral Diarrhoea Virus 2 (BVDV-2). A new group of viruses, known as atypical Pestiviruses or Hobi-like viruses, are currently not recognised as an official species (Bauermann et al., 2013). The two BVD viruses were typically presented as two genotypes of the same species (Ridpath et al., 1994) but these are now recognised as two independent species (King et al., 2011). However, the term genotype is still commonly used in the literature and both species are divided into multiple subgenotypes (Silveira et al., 2015; Sato et al., 2016). Currently, 16 BVDV-1 and three BVDV-2 subgenotypes have been identified (BVDV-1a to p and BVDV-2a to c) (Peterhans et al., 2010). The virus has a high antigenic variability, which means that new subgenotypes and strains of BVDV-1 and 2 are constantly being discovered (Neill, 2013; Ridpath et al., 2015).

Regardless of the species, BVD viruses present two biotypes, non-cytopathic (ncp) and cytopathic (cp). Cytopathic viruses are named after their ability to cause apoptosis of cultured cells (Kümmerer et al., 2000). The cytopathic effect is due to a change at the molecular level: ncp- BVDV strains express an intact non-structural protein known as NS2-3, while cp-BVDV isolates have undergone recombination or mutation processes and, in addition to NS2-3, they express NS2 and NS3 independently (Kümmerer et al., 2000). The marker for the cytopathic effect is NS3. The classification into biotypes has no implications on the virulence of the virus, which is dependent on the virus strain (Kelling et al., 2005; Glotov et al., 2016). Non-cytopathic strains can cause severe transient BVD infections (Peterhans and Schweizer, 2010) and the only time when cp strains are systematically more virulent than ncp is when they cause mucosal disease (MD) (see section 1.2.4.4). Traditionally, severe BVD outbreaks were always thought to be related to BVDV-2 (Ridpath et al., 2006), but these have also been reported in cases where BVDV-1 has been isolated (Ridpath et al., 2007; Strong et al., 2015; Glotov et al., 2016).

1.2.3. Epidemiology

1.2.3.1. Prevalence

In 2005 BVD was included in the World Organisation for Animal Health (OIE) list of cattle diseases and infections, although not as a notifiable disease (World Organisation for Animal Health, 2016b). The disease is spread worldwide, but the prevalence of BVDV-1 and 2 varies across countries. The most prevalent species worldwide is BVDV-1, although BVDV-2 has been found to have higher prevalence in America in comparison to other regions (Bolin and Ridpath, 1998; Silveira et al., 2015; Workman et al., 2016). Type two BVDV has been reported in several European countries (Letellier et al., 2010; Luzzago et al., 2014; Polak et al., 2014; Arduriz et al., 2015; Gethmann et al., 2015). In the UK, BVDV-1 is also the most common species (Vilček et al., 1999; Booth et al., 2013) and BVDV-2 has been reported (Wakeley et al., 2004), but not in recent years (Animal Health and Veterinary Laboratories Agency, 2014). Several studies have provided estimates for the overall prevalence of BVDV in different countries. In the absence of eradication programmes, the results have shown to be very variable with values of 18 to 97% of seropositive herds (Løken et al., 1991; Houe et al., 1995; Houe et al., 1999; Saa et al. 2012; Sarrazin et al., 2013; Machado et al., 2015) and these values are likely to vary over time (Brülisauer et al., 2010). The prevalence of persistently infected (PI) animals, that are key for the transmission of the disease and will be further discussed later in this chapter, is also very variable; however, it is estimated that they represent less than 2% of the cattle population (Bolin et al., 1985; Houe and Meyling, 1991; Houe et al., 1995; Taylor et al., 1995; Sarrazin et al., 2013).

Bovine viral diarrhoea virus can infect species other than cattle, including sheep, goats, deer, rabbits, camelids and pigs (Carman et al., 2005; Krametter-Froetscher et al., 2010; Passler and Walz, 2010; Tao et al., 2013; Ochirkhuu et al., 2016; Passler et al., 2016). These may act as reservoirs of the virus and their importance in the transmission of the disease will be discussed in section 1.2.3.3. In the UK, BVDV has been reported in deer (McMartin et al., 1977), alpacas (Foster et al., 2005) and rabbits (Grant et al., 2015).

1.2.3.2. Morbidity and mortality

Overall, BVD is a disease that causes high morbidity and low mortality. In the first reported outbreaks, the morbidity caused by BVDV was calculated at 33-88% and the mortalities varied between 4 and 8% (Olafson et al., 1946). Lower values have been described in recent years: in a study that followed unvaccinated weaned calves exposed to PI cattle, the morbidity rate ranged between 42 and 51%, while the mortality was 1-4.5% (Grooms et al., 2014). However, if virulent strains are involved, the mortality can reach higer values. In a severe outbreak caused by a BVDV-2 strain in Germany, where most herds were naïve to the virus due to the eradication scheme without vaccination, 29.5% of the affected animals died (Gethmann et al., 2015).

1.2.3.3. Transmission

The virus can be transmitted by direct contact between a naïve and a susceptible animal or by indirect contact with fomites. The most frequent route of transmission of BVDV is through oro-nasal secretions and naïve animals would go on to develop a transient infection (Müller-Doblies et al., 2004). However, if the exposed animal is pregnant, transplacental (vertical) transmission of BVDV is key in the epidemiology of the disease. Calves can be born persistently infected (PI) with BVDV if they are infected *in utero*, between 18 and 125 gestational days, prior to the start of the development of the foetal immune system (McClurkin et al., 1984; Grooms, 2004). These PI calves become immunotolerant to the virus, they do not recognise it as an external threat and cannot mount an antibody response against the virus (Chase, 2013). Animals PI with BVDV shed large quantities of virus in their body fluids, including nasal and ocular secretions, milk, urine, faeces, semen and foetal fluid and membranes (Houe, 1995), and they are the most important source of infection. The role of PI animals is essential for the maintenance of the virus in a population; however, transmission of BVDV has also been described in the absence of PI cattle (Moen et al., 2005). Transiently infected animals (TI) are able to transmit the disease if they contact a susceptible animal during the stage of viraemia, which usually lasts between 3 and 12 days (Müller-Doblies et al., 2004); however, they are considered epidemiologically less important (Niskanen et al., 2002; Lindberg and Houe, 2005; Sarrazin et al., 2014). Self-clearance of

BVDV has been described in herds where no PI cattle were present (Ståhl et al., 2008). Fomites can also be involved in the transmission of BVDV. Successful transmission of the virus has been described after using contaminated farming instruments (Gunn, 1993), needles and drug bottles (Gunn, 1993; Niskanen and Lindberg, 2003) and by sharing rectal gloves between PI and naïve cows (Lang-Ree et al., 1994). In a severe BVDV outbreak in Germany in 2012, veterinary practitioners were responsible for introducing the disease to at least three farms (Gethmann et al., 2015). Within the farm, the virus can survive in slurry for three weeks at 5°C (Bøtner and Belsham, 2012) and environments contaminated with amniotic and allantoic fluids, especially after the birth of a PI calf, can also be a source of infection (Lindberg et al., 2004). Airborne transmission of the virus has been described inside housing units or between close units that have air communication (Mars et al., 1999; Niskanen and Lindberg, 2003). Flies have been shown to carry the virus, but their role in BVD transmission is questionable (Tarry et al., 1991; Gunn, 1993; Chamorro et al., 2011). Indirect routes of transmission may become more important towards the end stages of eradication programmes (Lindberg and Houe, 2005).

Semen from TI and PI bulls is another source of BVDV. In different studies, when serving susceptible heifers with BVDV contaminated semen, only a small number of heifers seroconverted, but those that did were able to transmit the disease to other peers that had been served with non-contaminated semen and these gave birth to PI calves (Kirkland et al., 1991; Kirkland et al., 1994; Kirkland et al., 1997; Rikula et al., 2008; Newcomer et al., 2014). Contaminated frozen semen has been related to severe BVD outbreaks (González Altamiranda et al., 2012). In the case of TI bulls, after these have seroconverted, the risk of infection is likely to be much lower (Givens et al., 2003). In addition to transient and persistent infections, bulls have been reported to be affected by chronic testicular infections that will be briefly discussed in section 1.2.4.5. Two bulls have been confirmed to be affected by this type of infection in insemination centres (Voges et al., 1998; Newcomer et al., 1998) and when their semen was used in seronegative dams, PI calves were born (Niskanen et al., 2002). The current biosecurity measures and testing protocols applied at insemination centres should guarantee that the risk of transmitting the disease from artificial insemination is very low, but bulls should be considered when evaluating the risk of introducing the disease to the herd, especially in beef systems with natural mating. In the reproduction field, the role of infected embryos in the transmission of the disease has also been studied.

Embryos can be infected with BVDV when fertilised with infected semen or retrieved from PI cows; however, various studies have shown that the standardised washing processes greatly reduces the risk of transmission (Brock et al., 1997; Bielanski et al., 2013).

Sheep, goats and deer have been shown to be able to transmit BVDV to cattle in experimental and natural conditions (Uttenthal et al., 2005; Bachofen et al., 2013; Braun et al., 2014). This could have an impact as eradication schemes progress and the levels of virus in cattle populations decrease. The existing programmes do not monitor the presence of the virus in other species, although their importance has been discussed and there is currently no evidence to suggest that other species are important in the transmission of BVDV. In Spain, recent studies found that although wild and domestic ruminants shared BVDV isolates (Rodríguez-Prieto et al., 2016), there was likely to be very little transmission between both (Paniagua et al., 2016). Similar results were obtained in Norway where, although BVDV PI animals were found in wild cervids, the infecting strains were different from those isolated from cattle (Lillehaug et al., 2003). In addition, in Ireland the presence of sheep on the farm was not associated with higher number of BVDV positive results during the voluntary stage of the national BVD eradication programme (Graham et al., 2013).

1.2.4. Clinical presentations of BVD

The outcomes of BVDV infection vary greatly depending on the immune status and pregnancy status of the animal at the time of infection. The virus is able to cause a wide range of clinical syndromes that are discussed in this section.

1.2.4.1. Acute infections

When a naïve animal is exposed to BVDV it becomes acutely infected. Acute infections are transient and animals undergo a short period of viraemia (3-12 days post-infection) (Müller-Doblies et al., 2004; Pedrera et al., 2012). Depending on the virulence of the infecting strain, the animal may suffer from mild to moderate disease, although most acute infections remain subclinical (Liebler-Tenorio et al., 2003; Lanyon et al., 2014). Animals show clinical signs of disease between three and 15 days post-infection and the most common clinical signs

include high body temperature, depression, anorexia, diarrhoea and respiratory signs which include nasal discharge and coughing. Leucopenia with lymphopenia is also a feature of acute infections (Fredriksen et al., 1999; Liebler-Tenorio et al., 2003; Müller-Doblies et al., 2004; Kelling et al., 2005). Acutely infected animals develop neutralizing antibodies between two and three weeks after the initial infection and they are clinically recovered within three weeks (Fredriksen et al., 1999; Müller-Doblies et al., 2004). The exact duration of the levels of antibodies after natural exposure to BVDV is not clear. It has been shown that antibodies last for at least three years (Fredriksen et al., 1999), but immunity could be longer. Virulent strains of BVDV-1 and 2 are associated with a severe presentation of acute BVDV infections that, in addition to the clinical findings described previously, cause thrombocytopenia and mucosal ulceration (Ellis et al., 1998; Liebler-Tenorio et al., 2003; Hessman et al., 2012; Glotov et al., 2016). This syndrome is known as haemorrhagic syndrome, given the bleeding associated with the thrombocytopenia. Severe acute presentations of BVD could be confused with Mucosal Disease, a condition that only affects PI animals. Mucosal disease and the diagnoses of the different conditions caused by BVDV are discussed in sections 1.2.4.4 and 1.2.5 respectively.

1.2.4.2. Reproductive consequences of transient infections

Although the disease is named after its gastrointestinal signs, the effects that BVDV has on the reproductive function of cattle are responsible for the main losses in the herd (Houe, 2003). In infected animals, BVDV has been recovered from most parts of the reproductive tract of both female and male cattle and the reproductive consequences of the disease are well studied (Givens and Waldrop, 2004; Grooms, 2004; Lanyon et al., 2014). However, part of the pathogenesis is not completely understood yet.

In non-pregnant cows or heifers that are being served, BVDV infection causes infertility (McGowan et al., 1993; Fray, Mann et al., 2000; Fray et al., 2002). At the herd level, BVDV seropositivity has been associated with prolonged time-to-first calving in heifers, longer calving intervals in cows and increased numbers of services per conception (Niskanen et al., 1995; Rüfenacht et al., 2001; Valle et al., 2001). In TI and PI bulls, BVDV has been isolated from semen, but the virus seems to not affect the concentration, motility or the percentage

of live spermatozoa in semen (Kirkland et al., 1991; Kommisrud et al., 1996; González Altamiranda et al., 2012). If a pregnant naïve animal is exposed to BVDV, the outcomes of the infection depend on the stage of development of the embryo or foetus (Grooms, 2004). After fertilisation, studies suggest that the zona pellucida may protect the embryo from the virus. This means that until eight gestational days, embryos are likely not to be affected by BVDV (Brock et al., 1997; Fray, Paton, et al., 2000). Following this stage, it has been shown that the virus can reach the embryo before the placenta is fully developed (at around 25-30 days of gestation), causing early embryonic death (EED) (McGowan et al., 1993; Tsuboi et al., 2011). Once the placenta is functional, vertical transmission of BVDV can cause abortions at any stage, including late term abortions and the birth of stillborn calves (Blanchard et al., 2010), although immunocompetent foetuses are less likely to be affected. The immune system starts developing at around 120 gestational days and is not completely functional until 150 days. If the foetus survives abortion and is infected with BVDV before 125 days of gestation, the virus takes advantage of the underdeveloped immunity and causes immunotolerance, generating animals PI with BVDV (Stokstad and Løken, 2002; Peterhans and Schweizer, 2013). The birth of PI calves has been reported with infections as early as 18 days of gestation and as late as 125 days (Grooms, 2004). Since PI animals are the focus of one of the studies in this thesis, they are discussed in more detail in section 1.2.4.4. Once the foetus becomes immunocompetent, if infected with BVDV the virus will be cleared and the calf presents pre-colostral antibodies against BVDV at birth (Kelling and Topliff, 2013). These calves can be born normal; however, immunocompetent calves infected *in utero* have been reported to be more susceptible to secondary diseases (Muñoz-Zanzi et al., 2005). During the organogenesis of the different body systems, between 79 and 150 days BVDV has the ability to cause a wide variety of congenital malformations (Grooms, 2004; Agerholm et al., 2015). The nervous system is most commonly affected, with cerebellar hypoplasia being the most frequently reported malformation (Sprecher et al., 1991). Other neurological defects include hydrocephalus, hydrancephaly, pseudocyst formation and hypomyelinisation (Otter et al., 2009). The eyes can also be affected by BVDV with ocular and retinal degeneration, microophthalmia and congenital cataracts (Sprecher et al., 1991). Cranium malformations and brachygnatism have also been reported (Ross et al., 1986; Blanchard et al., 2010). Other types of abnormalities include thymic atrophy, renal dysplasia and bone and lung growth retardation (Liebler-Tenorio et al., 2004; Webb et al., 2012; Agerholm et al., 2015). Congenital malformations may overlap with periods of

immunotolerance, therefore calves born with congenital abnormalities could still be PI (Otter et al., 2009; Bachofen et al., 2010).

1.2.4.3. Immunosuppression and secondary disease

Bovine viral diarrhoea virus primary invades and replicates in lymphoid tissues (Pedrera et al., 2012; Bruschke et al., 1998). The virus has been shown to cause depletion of lymphocytes and to affect the normal function of macrophages (Chase, 2013), leading to immunosuppression and increased susceptibility to secondary diseases. Since the virus spreads to the whole body of infected animals, opportunist infections can be expected in most systems. However, respiratory disease is recognised as the most common complication after BVDV infection (Ridpath, 2010). The virus has been identified as an important component of bovine respiratory disease (BRD) syndrome (Fulton et al., 2000; Hay et al., 2016) and naïve animals exposed to BVD PIs have found to be twice as likely to be treated for respiratory problems (Grooms et al., 2014). Studies have suggested that the replication of the virus in lymphoid tissue in the lung is particularly high and this may explain the marked susceptibility to respiratory pathogens; similarly, the virus causes immunosuppression at the mesenteric and gut level, with particular effects in the Peyer's patches, which is likely to predispose to the diarrhoea observed during acute infections (Ellis et al., 1998; Bolin, 2002). Other conditions associated with acute BVDV infections include mastitis, although no evidence has been found to suggest that the virus would affect udder health in the long term (Waage, 2000; Berends et al., 2008); and there are occasional reports of cases of autoimmune diabetes mellitus in cattle thought to have been induced by BVDV (Taniyama et al., 1995; Tajima et al., 1999; Clark, 2003).

1.2.4.4. Persistent infections and mucosal disease

Persistent infections are caused *in utero* by ncp strains of BVDV-1 or 2 (Braun et al., 2014). Cytopathic BVDV strains have been shown to be unable to cause PI, which is likely to be due to a difference in the foetal immune response against different biotypes (Chase et al., 2004). After birth, if a PI animal's ncp strain becomes cp by genetic rearrangement

(recombination, duplication, translocation or mutation) or if the animal is super-infected by a cp strain, the PI develops mucosal disease (MD) (Brownlie et al., 1984; Kümmerer et al., 2000; Peterhans et al., 2010). Mucosal disease presents with ulceration of the gastrointestinal tract, from the oral cavity (gums, tongue, cheeks, palate) to the abomasum and small intestine. Interdigital and coronary band ulceration are also common findings and these can result in severe lameness. Affected animals are usually pyrexic, anorectic, depressed and suffer from severe diarrhoea that can present fresh blood or melena. Mucosal disease cases quickly deteriorate clinically and all animals die within weeks of the onset of clinical signs (Bolin, 1995). Initially, the disease was described to affect cattle under two years of age, but older animals have also been shown to be affected (Brownlie, 1985; Bachofen et al., 2010).

Traditionally, PI cattle have been described as having retarded growth rates, to be ill thriven and to have increased mortality rates (Taylor et al., 1997; Stokstad and Løken, 2002; Kane et al., 2015). Animals PI with BVDV have been shown to have lower levels of thyroid hormones (Larsson et al., 1995). This, combined with the fact that BVDV can impair the growth of long bones (Webb et al., 2012) and lead to higher susceptibility to secondary diseases (Bolin, 2002; Peterhans et al., 2003), may account for the poor condition and stunted appearance of some PI cattle. However, many PIs have normal growth rates and live for years; the oldest PI identified during the Swiss eradication scheme was 11 years old (Presi and Heim, 2010). Regarding the reproductive function of PI cattle, studies have reported decreased fertility in persistently infected cows (Muñoz-Zanzi et al., 2004) and a case of testicular hypoplasia has been reported in a PI bull (Borel et al., 2007). However, most PI animals are able to reproduce and, more importantly, PI dams always give birth to PI calves (Lanyon et al., 2014). As discussed in section 1.2.4.2, semen from PI bulls has been shown to be of acceptable quality and, although the fertilization may be affected in some cases, they are able to transmit the disease to susceptible dams (González Altamiranda et al., 2012).

1.2.4.5. Chronic infections

In 1994, an immunocompetent, non-viraemic bull was found to be constantly shedding virus in semen (Voges et al., 1998). The bull had constantly high antibody titres and the quality of the semen was not affected, but disease was successfully transmitted to one of three naïve

heifers that were inseminated with frozen semen (R. Niskanen et al., 2002). The virus was isolated from the animal's semen until the day of its euthanasia. Investigation of the case led to the assumption that the infection was localized in the testes, protected by the blood-testes barrier. A second case of persistent testicular infection was confirmed years later (Newcomer et al., 2014). Attempts have been made to reproduce persistent testicular infections experimentally, but the persistence of virus in semen was shorter and these cases were denominated 'prolonged testicular infections'. Prolonged BVDV infections have been reported in other immunoprivileged organs, including the ovarian tissue, the central nervous system and circulating leucocytes (Gogorza et al., 2005; Collins et al., 2009). Experimental transmission of BVDV was successful when susceptible animals received blood from animals that had persistence of BVDV in leucocytes after a transient infection (Collins et al., 2009). Although further research is needed to fully understand the pathogenesis and importance of chronic BVDV infections, the existing literature suggests that they are likely to represent a low risk of transmission of disease (Givens and Marley, 2013).

1.2.5. Diagnosis

Bovine viral diarrhoea can be diagnosed through the detection of the BVDV antigen or antibodies and recent reviews of the available methods can be found in the literature (Sandvik, 2005; Dubovi, 2013; Lanyon et al., 2014). Virus isolation in cell cultures has traditionally been considered the gold standard for the diagnosis of BVDV. However, this technique can be affected by several factors (Dubovi, 2013) and new, very sensitive and specific tests like reverse transcriptase polymerase chain reaction (RT-PCR) are currently accepted as new reference tests (Lanyon et al., 2014). Antigen-detection tests include the aforementioned RT-PCR and antigen ELISA tests (Ag-ELISA). Both methods can be used in a variety of samples including serum or plasma, milk and tissue. Samples can be pooled and tested with RT-PCR, but not with Ag-ELISA. It has been shown that RT-PCR has higher sensitivity and may detect lower levels of virus, i.e. transient infections, whereas ag-ELISAs may miss some transient infections (Hanon et al., 2014). Immunohistochemistry (IHC) and immunofluorescence (IFA) are other antigen-detection techniques, with IHC being more reliable than IFA. However, they can only be used in tissue samples and require more resources (fixation of the sample in formalin, processing of the biopsy sample, etc.).

Antibody ELISA (Ab-ELISA) and virus serum neutralisation (SN) are the techniques available to test for BVDV antibodies.

When dealing with the diagnosis of individual BVD cases and antigen testing, it is commonly accepted that two samples are needed to distinguish between transiently and persistently infected animals (Lanyon et al., 2014). Transiently infected animals give a positive antigen result if sampled during the viraemia stage. In these animals the level of antigen decreases as neutralising antibodies develop and two to three weeks after the initial infection they present neutralising antibodies, becoming antibody positive and antigen negative on subsequent tests (Hanon et al., 2014). By contrast, the presence of BVDV antigen in PI animals is constant throughout the animal's life and it can be detected in most of the animal's tissues (Liebler-Tenorio et al., 2004). The guidance for the Scottish BVD Eradication Scheme stipulates three weeks as the minimum testing interval to confirm a persistent infection (The Scottish Government, 2015b), although some references suggest to wait at least four weeks before re-test (Lanyon et al., 2014). The presence of maternal antibodies in young calves can interfere with certain diagnostic tests for antigen by neutralising the BVDV antigen in PI calves to undetectable levels (Zimmer et al., 2004). This can be avoided by using RT-PCR or antigen capture ELISA (ACE) in skin biopsy samples (Larska et al., 2013; Dubovi, 2013). Recently, the case of an assumed-PI animal that presented decreasing levels of antigen has been reported (Fux, 2015). Cases like this will need further study, but this may question the belief that there is a clear distinction between transiently and persistently infected animals. Animals PI with BVDV were traditionally assumed to be always antibody negative. However, it has been shown that PIs can react and become BVDV seropositive when exposed to heterologous strains of the virus (Fulton et al., 2003). Therefore, when suspecting persistent infection, animals should be tested for antigen even when an antibody positive result has been obtained.

At the herd level, bulk tank milk (BTM) test can be used to monitor antibody levels and or the presence of antigen in milking animals. However, when used to monitor antibody levels in dairy farms, these need to be interpreted with caution taking into account the herd characteristics. Bulk tank milk tests can detect antibodies that have been circulating in the herd for up to three years, either as a result of natural exposure or vaccination (Houe, 1999). In addition, when screening a whole herd, BTM tests always need to be complemented with

testing of animals that are not contributing to the milk tank (i.e. youngstock, pregnant heifers and dry cows) (Lindberg and Alenius, 1999; Lanyon et al., 2014).

Pregnant cattle that carry BVD PIs represent a challenge to the diagnosis of the disease. These are known as 'trojan cows' due to the fact that the PI animal cannot be confirmed until the calf is born. Some diagnostic methods have been suggested to diagnose trojan PI calves, although they are not commonly used. One of them is based in the fact that dams carrying PI calves present higher antibody titres, especially towards the end of the gestation (Lindberg et al., 2001). The detection of viral RNA in foetal fluids has also been used, but is a more complex process and requires sedation and anaesthesia (Lindberg et al., 2002).

When BVDV is involved in abortions and congenital malformations, the lesions caused in the foetus and placenta are not pathognomonic (Grooms, 2004). It is difficult to associate BVDV with abortions unless seroconversion of the dam is demonstrated or the virus is isolated from the calf. In the case of malformations, the animal may present antibodies against BVDV at birth, prior to colostrum intake, but this may not be the case in all of them since malformations can occur before the immune system is completely functional (Agerholm et al., 2015). In addition, neurological deformities may also be caused by other viruses (e.g. Schmallenberg or Bluetongue) and non-viral causes are usually undistinguishable from those associated with BVDV (Agerholm et al., 2015).

Diagnosis of mucosal disease (MD) cases is usually based on the confirmed BVD PI status of an animal, as discussed above, and the presence of gastrointestinal tract ulceration on the post-mortem (PM) examination. However, a definitive diagnosis of MD requires isolation of the cp-BVDV strain from the affected animal (Bachofen et al., 2013; Lanyon et al., 2014). On gross PM examination, the presentation of PI animals that have not succumbed to MD and animals that have been TI is very variable. Both TI and PI animals can present without gross significant PM lesions. However common findings include atrophy of lymphoid organs, including lymph nodes, Peyer's patches, thymus, and the bone marrow, and gastrointestinal ulceration (Ellis et al., 1998; Liebler-Tenorio et al., 2003; Hessman et al., 2012; Romero-Palomo et al., 2015). Lesions associated with secondary infections due to the immunosuppressive effects of the virus are also commonly reported in TI and PI cattle

(Hessman et al., 2012), pneumonic lesions being one of the most frequent findings (Taylor et al., 1997; Bachofen et al., 2010)

1.2.6. The economic cost of BVD

Bovine viral diarrhoea has been recognised as a disease that can have a significant economic impact on cattle production systems. Depending on the strain involved and the level of immunity of the herd, BVDV infection may result in low pregnancy rates, increased calving intervals, decreased growth rates, decreased milk production and increased drug costs and mortality due to secondary disease (Rüfenacht et al., 2001; Houe, 2003). In 2004 it was estimated that an endemically infected Scottish beef herd where no measures are applied to control BVD would lose £37 per cow per year (Gunn et al., 2004). Similar costs have been suggested for suckler herds in Ireland, with €32 per cow and year (Stott et al., 2012). In the USA, a higher value was found: exposure of feedlot cattle to PI animals was estimated to generate losses of $88 per animal (Hessman et al., 2009). Losses in feedlots are likely to be higher due to the impact that BRD has in these units (Campbell, 2004). The perception is that costs are higher for dairy farmers due to the negative consequences on fertility and milk production (Fourichon et al., 2005; Heuer et al., 2007; Stott et al., 2012). The disease was estimated to cost €63 per cow per year in a dairy herd in Ireland (Stott et al., 2012) and in France between €10 and €19 were lost per 1,000 litres of milk depending on the severity of the outbreak (Fourichon et al., 2005).

1.2.7. Control of BVD

When aiming to control BVD at a herd level, removing PI cattle is key to reducing the virus circulation in the herd. A study performed during the Irish eradication scheme found that herds that retained BVDV PIs were more likely to have new BVDV antigen positive animals the following year (Graham et al., 2015). When PIs are removed, the control of the disease is much easier. However, transmission of the disease has been reported in the absence of PI cattle (Moen et al., 2005) and the efforts to remove infected animals from the herd are likely to be useless if these are not accompanied by measures aimed at avoiding new exposures to

the virus. Biosecurity can be considered the basis of BVD control and eradication (Lindberg and Houe, 2005). Buying animals in has been reported as one of the most common sources of infection (Lindberg and Alenius, 1999; Bitsch et al., 2000; Rikula et al., 2005). Herds with an open status, where animals from external sources are routinely bought in, are at a higher risk of infection, especially when introducing cows with calves at foot and pregnant dams, which carry the risk of being 'trojan cows' (Graham et al., 2013; Gates et al., 2014). If cattle are bought into a herd, it is recommended that these are isolated and tested for BVDV antigen and antibody (Smith and Grotelueschen, 2004). Bought-in pregnant dams with positive antibody should be isolated and their calves tested at birth, since they could be 'trojan' cows carrying PI calves. Another very common source of exposure to BVDV is contact with infected neighbouring stock during grazing (Smith et al., 2014). Recommended measures to avoid this contact include double-fencing – this is leaving a distance of at least one meter between neighbouring fields (Lindberg and Houe, 2005; Gates, Woolhouse, et al., 2013), and to keep pregnant cattle and youngstock away from neighbours since these are the groups most susceptible to high losses. Sharing pastures between different herds, which is a common practice in some European regions, has also been associated with a higher prevalence of BVDV and should be avoided when possible (Presi et al., 2011; Graham et al., 2013). Contaminated environment or material used by farmers or veterinarians can also be a source of infection (Gethmann et al., 2015) and these should be taken into account when visiting various farms that may have different BVDV status. In 2004, the Finish control scheme included additional measures to avoid the transmission by fomites (Rikula et al., 2005)

When biosecurity measures have been applied and the virus has been eliminated from the herd, monitoring for BVDV is necessary to promptly detect new infections and react quickly (Lindberg and Houe, 2005). The different diagnostic approaches to monitor, control and eradicate BVD are discussed for national eradication programmes in the next section, but the same principles can be applied to the herd level.

Cattle can be protected against BVDV infections when provided with immunity against the virus. Passive immunity from maternal colostrum is the first chance for animals to get protection against BVDV. The duration of maternal antibodies is variable, it depends on the level of immunoglobulins (Ig) absorbed by the calf, which partially depends on the

colostrum's Ig concentration. Colostrum replacements have been shown to provide adequate immunity against BVDV at more constant levels, with less variability in the level of protection than natural, maternal colostrum (Chamorro et al., 2014). Passively derived antibodies may start decreasing between four and nine months of age, but in some cases they may persist for longer periods (Coria and McClurkin, 1978; Menanteau-Horta et al., 1985; Muñoz-Zanzi et al., 2002), Once maternal protection has expired, calves become seronegative. If exposed to the virus, naturally developed antibodies provide long term immunity that has been shown to last at least three years (Fredriksen et al., 1999). Controlled exposure of cattle to BVDV PIs prior to breeding or before entering a feedlot has been shown to successfully prevent the negative consequences of acute infections (Rodning et al., 2012; Grooms et al., 2014), but this practice is always associated with a degree of risk and is not recommended (Lindberg and Houe, 2005).

For those animals without natural immunity to the virus, inactivated or killed and modified-live (MLV) vaccines are available. Various articles have been published that review both types of vaccines (Kelling, 2004; Newcomer and Givens, 2013). Inactivated vaccines are generally known to be safer, since the inoculated virus cannot replicate; however, they induce weaker and shorter immune responses (six months) that require two initial doses and are effective one to three weeks after a primary vaccination schedule (Peters et al., 2004). Modified live vaccines, however give higher antibody responses that give earlier protection (five to seven days post-vaccination) (Brock et al., 2007) and last up to one year (Purtle et al., 2016). Risk of virulence reversion has been reported with MLV although safer vaccines have been developed (Newcomer and Givens, 2013). A recent study has shown that vaccinating animals with a MLV during late pregnancy, at drying-off, can significantly increase the levels of antibodies in colostrum without having negative consequences on the dam or foetus (Smith et al., 2015). The ability of MLV to produce an antibody response has been shown to be negatively affected by the presence of maternal antibodies in young calves (Ellis et al., 2001), although controversial results exist regarding this finding (Menanteau-Horta et al., 1985). In addition, it has been shown that MLV can produce effective responses in calves that had received BVDV antibody positive colostrum when vaccinated as early as five weeks old (Zimmerman et al., 2006). Traditionally, most vaccines only included BVDV-1; however, cross-reactivity between different strains of both BVDV-1 and 2 has been reported (Kelling, 2004; Hamers et al., 2008).

Regardless of the type of vaccine used, vaccination against BVDV has been shown to reduce the risk of foetal infection, decrease abortion rates, improve pregnancy rates (Newcomer et al., 2015) and is effective in preventing acute infections (Purtle et al., 2016). Neither inactivated nor modified live vaccines are a hundred percent effective (Fulton et al., 2005). In addition, vaccination protocol compliance can also affect vaccination efficiency (Rauff et al., 1996; Graham et al., 2004; Moennig et al., 2005; Meadows, 2010), therefore vaccines should always be used in conjunction with biosecurity measures and disease surveillance to prevent and control BVD (Lindberg and Houe, 2005; Smith et al., 2014).

1.2.7.1. Eradication schemes

The first attempts to eradicate the disease were made in the 1990s by the Scandinavian countries: Norway (Valle et al., 2005), Sweden (Hult and Lindberg, 2005), Denmark (Bitsch et al., 2000) and Finland (Rikula et al., 2005). Since then, many European countries have followed their example and established new eradication programmes (Lindberg et al., 2006). Outside Europe, Australia and the USA are discussing options to eradicate the disease (Lanyon and Reichel, 2014; Givens and Newcomer, 2015). The Scandinavian approach to BVD eradication was based on initial serological testing of herds, followed by virological investigations to detect the source of virus in those herds classified as infected; the use of vaccines is banned (Bitsch et al., 2000; Hult and Lindberg, 2005; Rikula et al., 2005). After ten years of eradication, the Scandinavian countries were considered free of BVDV (Lindberg et al., 2006). In 2008, Switzerland launched an eradication programme with a different strategy (Presi and Heim, 2010). The stages of the Swiss scheme included testing of all cattle for BVD virus during the first year, testing of all new-born calves during the second year and monitoring thereafter. Vaccines were also banned and the removal of confirmed PI animals was compulsory. Following this approach, the prevalence of virus-positive animals in Switzerland decreased from 1.8% to 0.2% in only two years (Presi et al., 2011). The example of Switzerland has been followed by Germany, although vaccines are allowed in areas with higher prevalence, after a severe outbreak occurred in herds that had become naïve to the virus (Gethmann et al., 2015). Northern Ireland and the Republic of Ireland have based their eradication programmes on tag testing of all new-born calves, but

vaccination is allowed (Stott et al., 2012). Overall, all the models have found that the eradication of BVDV would be economically beneficial for the cattle industry (Reichel et al., 2008; Häsler et al., 2012; Løken and Nyberg, 2013; Stott et al., 2012), although differences exist between approaches (Santman-Berends et al., 2015). In answers to a survey carried out in the UK in 2015, the main reason cited for joining an eradication scheme was higher profitability (65% of farmers) and farmers that had already joined a programme believed that cattle were healthier (75%), that the overall productivity improved (39%) and that they were perceiving better prices when selling stock (33%) (Price, 2015).

1.2.8. Bovine Viral Diarrhoea in Scotland

1.2.8.1. Prevalence in Scotland

Between 1975 and 1978, Moredun Research Institute identified BVDV, then referred to as 'mucosal disease virus' (MDV), in 25% of the samples submitted for enteritis in adult cattle, 4% of respiratory disease cases, 5% of reproductive disease and 8% of samples categorised as 'others' (Snodgrass et al, 1980). Years later, between 1996 and 2002, SRUC recognised a decreasing trend in the cases of mucosal disease, fetopathies and congenital diseases associated with BVD. Between 2002 and 2009 the percentage of abortions due to BVDV remained at a mean of 2.9% of the total abortion cases submitted to the SRUC (SAC Consulting Veterinary Services, 2010). In 2010 it was estimated that 16 % of Scottish beef suckler herds had active infection (presence of a PI in the herd), while 69% were not recently exposed to the virus. The remaining 16% could not be classified in either category (Brülisauer et al., 2010). In the dairy herd, in 2012, it was estimated that only 12.7% of the herds had low prevalence of seropositive cows in bulk milk tank tests, while 65% and 20.5% of the herds had moderate or high prevalence of seropositive cows, respectively (Humphry et al., 2012). To the author's knowledge, no studies have been published regarding the specific BVDV-1 and 2 prevalence in Scottish herds. In a herd outbreak reported by SAC Consulting Veterinary Services in 2007 (SAC Consulting Veterinary Services, 2007), a BVD outbreak caused a morbidity of 30-36 % and a mortality of 19 % in a group of 36 yearlings, with at least 4 dead animals affected with mucosal disease.

1.2.8.2. The Scottish BVD Eradication Scheme

Following the example of the Scandinavian countries, in 1994 the Shetland Islands made the first attempt to eradicate BVD on Scottish land (Synge et al., 1999). The disease was successfully controlled in the archipelago in only three years and Shetland became free of BVD in 1997. In 2001, Orkney started a compulsory scheme, which had a very good response during the initial years. However, since 2006 almost no changes were observed in the BVD prevalence and re-infection was still occurring in 2008 (Truyers et al., 2010). In 2010, with the support of the industry and the veterinary sectors (The Scottish Government, 2010b), the Scottish Government launched a nation-wide BVD Eradication Scheme, aiming to continue improving the Scottish livestock health status and the standards and reputation of Scottish farming (The Scottish Government, 2010c). The scheme started with a stage of subsidised screening that ran between September 2010 and April 2011 and 4,000 herds took part in it (33.4% of cattle herds in 2010) (The Scottish Government, 2015a; The Scottish Government, 2016b). During the second stage, all breeding cattle herds had to be tested for BVD before 1st February 2013 and annually thereafter. Six testing methods were allowed during this stage, including: antibody check test in calves, testing all calves for virus, testing all animals for virus and, only for dairy herds, an annual bulk tank milk antibody test and blood testing heifers, four quarterly bulk milk tank tests and a first lactation composite milk test (The Scottish Government, 2014). Herds are given a 'negative' or 'not negative' status based on the annual screen result. In 2013 the eradication scheme database became operative on ScotEID (ScotEID, 2016). Since then, all members of the public can access the database to look up and check an individual animal's test results and/or herd's status based on the ear tag or County Parish Holding (CPH) number respectively. In January 2014, with the start of the third stage, the first control measures came into effect: animals identified as persistently infected with BVD could no longer be moved or sold, all herds had to declare their status before selling animals and restrictions were applied to those herds that failed to meet the mandatory testing requirements. Finally, in June 2015 Scotland entered the fourth stage of the scheme and new legal restrictions were applied. Currently, PI animals can only be moved directly to slaughter and animals from 'not negative' herds cannot be moved to other farms unless individually tested for virus (and with a negative result), and any animals entering a herd from an untested source must be tested for virus (The Scottish Government, 2015b). In addition to the 'not tested', 'negative' or 'positive' BVDV status for individual animals, a

new status has been added for dams that have had a calf that tested negative on antigen tests. These are 'assumed negative' cows and can be moved from not negative herds without being individually tested. The testing options have been reduced to only four: the calf antibody checks have been maintained for block calving beef or dairy herds, as well as the options of testing all calves or animals for virus and a new option has been introduced, which consists of testing calves for antibody every six months for dairy herds that calve all year round (The Scottish Government, 2015b).

Before the start of the Scheme it was calculated that 40% of Scottish herds were exposed to BVDV (not-negative). By the end of 2015 the prevalence had been reduced to 12.5% (The Scottish Government, 2016d). Initially, only 23% of beef herds were exposed to BVD, as opposed to 52% of dairy herds (The Scottish Government, 2012). It was expected that removing the BTM tests would help accelerate the eradication process in dairy herds, since BTM tests can detect antibodies in milk due to historic infection or vaccination and may not accurately reflect what is going on in the herd at the time of testing (Lindberg and Alenius, 1999). Furthermore, evidence shows that farmers re-test animals quicker if a positive antigen result is obtained from a blood rather than a milk sample (Duncan et al., 2016). By August 2016 over 4,700 animals in total had been confirmed as PI and the number of PI cattle identified per year increased from 759 and 742 in 2013 and 2014 respectively, to 1,479 in 2015 (J. Purcell, personal communication, August 2016), which clearly suggests that the removal of the BTM tests has been beneficial to the eradication process. However, 472 of these PI cattle were still alive in August 2016 and as a consequence new infections are still likely to occur (Graham et al., 2015). To the author's knowledge, no studies have been published yet to support the progress made by the Scottish BVD Eradication Scheme. Using data from the 2006-15 BVD PI SCPAHFS caseload, Chapter 5 presents the analysis of clinical records of PI cattle and assesses any changes in their clinical presentation that may have happened as a consequence of the launch of the Scheme.

2. Materials and Methods

2.1. Background: The Scottish Centre for Production Animal Health and Food Safety

The University of Glasgow's School of Veterinary Medicine celebrated its 150th anniversary in 2012. The school was initially based at Buccleugh Street in the city centre but it later moved to Gilmorehill, where it stayed until the 1950s before moving again to its current location at the Garscube Estate (Yam et al., 2012). Historically, the farm animal buildings were known as 'the Byres', three blocks of animal buildings that were completely remodelled in 2010. Since the establishment at Garscube, the farm animal department has worked closely with the pathology group. The post-mortem facilities are located next to the Byres. Farm animal cases are donated to be used for teaching and receive full diagnostic work-up and necessary treatments. When an animal is euthanased, a full gross post-mortem (PM) examination is performed by the Anatomical Pathology Department.

In 2011, after remodelling of the Byres, the Scottish Centre for Production Animal Health and Food Safety (SCPAHFS) was created. The SCPAHFS comprises a team of farm animal and public health lecturers and clinicians. The main aim of the SCPAHFS department is to teach under- and post-graduate veterinary students as well as providing services to external farms, including the University owned Cochno Farm, advise veterinary surgeons and take part in farm investigations. Central to the SCPAHFS department is the Galloway Building. The Galloway Building is a farm animal clinic that receives farm animal cases donated from farmers via a referring veterinary surgeon. These cases are used for teaching veterinary students and receive a diagnostic work up as detailed below. The Galloway Building case load generates a large amount of animal health data that are currently not used for surveillance purposes.

2.1.1. Admission of cases and daily routine at the Galloway Building

The SCPAHFS receives animals referred by first opinion practitioners and farmers across Scotland and northern England. Although typically uneconomic cases or cases in which a diagnosis could not be reached, individual animals can be sent as part of a herd or flock investigation. All animals are used for teaching purposes. Although the final (fifth) year Bachelor in Veterinary Medicine and Surgery (BVMS) students have the greatest involvement with these cases, those in second, third and fourth year also utilise them in developing clinical examination and clinical reasoning skills. Farm animal Junior and Senior Clinical Scholars (interns and residents, respectively) and post-graduate students also get involved with the cases. Additionally, the SCPAHFS receives students undertaking work experience, visitors from veterinary schools across Europe, farmers' meetings organised through the National Farmers Union (NFU) Scotland and helps with the delivery of Official Veterinarian (OV) training courses, all of whom are exposed to the case load of the Galloway Building.

The process of admitting an animal to the Galloway Building starts with a first opinion veterinary practitioner contacting the SCPAHFS. The referring veterinarian and a clinician from the SCPAHFS discuss the case and the clinician completes a history form (see Appendix 1). The referring veterinarians are always asked to confirm that the animal is fit for transport (Anon, 2005). Once the case is confirmed fit for transport, the SCPAHFS clinician will phone the farmer and take a history from the farmer (see Appendix 1). The clinician will arrange the transport of the animal, which is carried out by one of the University's stockpersons free of charge. All cases are admitted as donations to the University of Glasgow, and a payment of £40 and £20 as a gesture of gratitude is offered for each cattle and sheep case respectively. If a farmer refers two animals with the same clinical presentation, only one payment is made. At the time of collection, the farmer or owner signs a consent form certifying the donation of the case to the University of Glasgow for teaching and research purposes (Annex 1).

Until 2012 the farm animal rotation in the fifth year of BVMS ran from September/October to May, with a four-week break during Christmas. With a reorganisation of the teaching in 2013, the rotation now runs for ten blocks of four weeks, with a four-week break in

July/August and four more weeks in December/January. During the final year farm animal core rotation, each final year student spends two weeks in the Galloway Building.

When a new animal arrives the clinician on duty performs a general assessment of the animal. If the animal is distressed or tired after the transport, especially after longer journeys, it will be left to rest in the pen before proceeding with a full clinical examination (unless emergency treatment is required). Each case is assigned to a pair of students who perform the first full clinical examination of the animal, supervised by a clinician. Animals are weighed and blood samples are taken for diagnostic purposes. The students perform an in-house packed cell volume (PCV, haematocrit) and a total protein (TP). Heparin- and EDTA-anticoagulated blood samples are routinely sent for a basic biochemistry profile and full haematology. Students are required to manage cases on a daily basis, this includes clinical examinations, diagnostic interventions and treatments. The animals' diagnoses, progression and plan are discussed at daily rounds with the clinician and resident or intern on duty in the Galloway Building. In addition to the routine bloods taken after the animal's admission, ancillary tests are performed as needed. These include tests such as parasitology, serology, cytology, urinalysis, ultrasound (US) scans and biopsies. Radiographs, post-mortem Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans may be performed in specific cases. The decision when to euthanase an animal is always based on the welfare of the animal and prognosis of the clinical diagnosis. Occasionally animals do respond to treatment and cases are either sold direct to an abattoir or remain in the Galloway Building as static teaching cases. Following euthanasia of any animal in the Galloway Building, the Anatomical Pathology Department performs full gross PM examination on these cases and a PM report is produced. Samples for histopathology are taken in cases of special interest or when the owner is willing to pay for further testing. The PM examinations provide important information to the case picture and very often will provide or confirm a final diagnosis. After each post-mortem examination findings are communicated via a phone call to both the referring veterinarian and the farmer. When the final PM report is received, the intern or resident that admitted the case will write and send a letter to the referring veterinary surgeon summarising the progression and findings in that particular animal. In those cases where diagnostic work up detects issues that could have herd or flock implications, contact with the referring veterinarian and farmer is made as soon as possible.

2.1.2. Data storage and recording

Each case admitted to the SCPAHFS is identified with a case number, which is generated by a practice management system (AT Veterinary Systems, 2016), where the animal's ear tag, species, breed, sex and date of birth are recorded. The owner details (farmer's name, farm address, postcode and contact numbers), referring practitioner and veterinary practice are also recorded in the same database. Case labels are printed using the AT System and these will be used to identify the animal's case file, samples and laboratory submission forms. The case file is a paper folder that contains all its information, such as the case labels (see Appendix 3), the farmer and veterinary surgeon history forms (See Appendix 1), a copy of the animal's passport (if applicable), the clinical examination sheet completed by the students during the animal's first full exam (Appendix 4), the daily progression or TPR (temperature, pulse, respiration) sheets (Appendix 5), an additional diagnostic results sheet (Appendix 6) and a communication sheet where any conversations with the farmer or veterinarian are recorded (Appendix 7). Diagnostic reports (biochemistry, haematology results and additional tests) (Appendices 8 and 9) will be added to the case file as they are received. When an animal is euthanased, the case file is transferred to an envelope that is also identified with a case label. These 'dead' case files are stored in numerical order (based on the case number) and have been kept in the SCPAHFS offices since the 1960s.

In addition to the paper case file, an electronic case folder is created for each case under the Department's secure network drive. The electronic copies of laboratory and post-mortem reports, as well as the letter to the referring veterinarian and any images are saved in this folder. Since 2004, summaries of every animal admitted to the SCPAHFS have also been recorded in Microsoft (MS) Office Excel (see Table 2.1). In January 2015, four new columns were added to the spreadsheet: species, sex, farm postcode and clinical diagnosis (reached at the SCPAHFS).

'SCPAHFS cases' spreadsheets
▪ Date of admission
▪ Initials of the intern/resident on clinics
▪ Initials of the clinician on clinics
▪ Ear tag
▪ Age
▪ *Species*
▪ Breed
▪ *Sex*
▪ Owner's name
▪ *Farm postcode*
▪ Referring veterinarian's name
▪ Veterinary practice
▪ Referring diagnosis
▪ *Clinical diagnosis*
▪ Post-mortem date
▪ Post-mortem diagnosis

Table 2.1 MS Office spreadsheet structure. The fields added in 2015 appear in italics.

2.2. Ethics approval

For the three retrospective studies and the case study presented in chapters three to six, ethical approval was granted by the Ethics & Welfare Committee of the School of Veterinary Medicine of the University of Glasgow.

2.3. Data collection and cleaning

2.3.1. Analysis of SCPAHFS caseload (2006 – 2015)

Data for this study were obtained from the 2004-15 MS Office Excel spreadsheets. Only 11 cases were recorded in 2004-05 therefore these years were excluded. A new spreadsheet named 'Cases 2006-15' was created with a copy of all the cases recorded in the original file between January 2006 and December 2015. The following fields were added to the new file: species (cattle, sheep, pigs, goats, and alpacas), type (dairy or beef, only for cattle cases), years old, farm postcode and affected system. The post-mortem date and diagnosis fields

were missing for more than 50% of the cases and were therefore excluded. Table 2.2 shows all the fields included in the 'Cases 2006-15' spreadsheet. The original 'referring diagnosis' field included both clinical signs and diagnoses and the column's title was changed to 'referral reasons'.

'Cases 2006-15' spreadsheet
▪ Case number
▪ Date in
▪ Species
▪ Breed
▪ *Type* (dairy or beef, only for cattle)
▪ Age
▪ Years old
▪ Owner
▪ Farm postcode
▪ Practice
▪ *Referral reason - Affected system*
▪ Referral reason

Table 2.2 Categories included in the spreadsheet used for the 2006-15 caseload analysis. The fields in italics were added to the new spreadsheet.

The breeds, owners' and practices' names were checked for misspellings and where information was missing, the AT System was consulted to confirm the missing information. The correct names of the veterinary practices were also checked on the internet, using the practice's website and/or the Royal College of Veterinary Surgeons (RCVS) directory (Royal College of Veterinary Surgeons, 2016). If the farm's postcode was missing on the AT System, this was obtained by searching the farm's address online (Google, 2016; Streetmap EU Ltd, 2016). Postcodes that could not be identified were marked as 'missing'. At the same time, the practices' location (latitude and longitude) was obtained from Google Maps with the aim to calculate the distance by road to the SCPAHFS (Google, 2016). The referral reasons were also checked for misspellings and similar expressions were grouped under one term, e.g. 'chronic pneumonia' and 'pneumonia' were grouped under 'pneumonia', 'ill thrift', 'stunting' and 'weight loss' were grouped under 'alterations of body weight and/or size'. Finally, referral reasons were assigned to an 'affected system'. Although the VIDA report is based on diagnoses and not clinical signs and comparison with the SCPAHFS' referral reasons was not possible, the 'affected system' categories were

established using the VIDA report groups (Animal and Plant Health Agency, 2015c). In addition to the different body systems and ‘diagnosis not reached’ and animals with ‘no clinical problem’ that are already included in VIDA, the classification in this study also included a category for ‘diagnosis not recorded’ for those cases were a referral reason was missing on the Excel spreadsheet. The categories are summarised in table Table 2.3.

Affected system
▪ Systematic disease and those not readily classified organically
▪ Digestive system
▪ Respiratory system
▪ Urinary system
▪ Musculo-skeletal system
▪ Nervous system and organs of special sense
▪ Skin
▪ Blood and lymph circulatory and poietic systems
▪ Reproductive and mammary system
▪ No clinical problem
▪ Diagnosis not reached
▪ Diagnosis not recorded

Table 2.3 Categories of affected systems.

With the aim to compare the SCPAHFS caseload with the Scottish livestock population and the submissions to the VIDA database, the total numbers of cattle, sheep, pigs, goats and alpacas in Scottish holdings in June 2006-15 were obtained from the 2006-15 Economic Report on Scottish Agriculture (The Scottish Government, 2016b) and the total number of samples per species submitted to VIDA were retrieved from the 2013 and 2014 reports (Animal and Plant Health Agency, 2014c; Animal and Plant Health Agency, 2015c). With the aim to compare the age distribution within the SCPAHFS caseload, cattle and sheep cases were grouped into categories following the classification used in the Economic Report on Scottish Agriculture (The Scottish Government, 2016b). Cattle were grouped into three categories: ‘under one year old, ‘between one and two years old’ and ‘two years old and over’. Sheep were divided into two groups: ‘under one year old’ and ‘one year old and over’.

2.3.2. Diagnoses reached at the SCPAHFS in 2015 and comparison to the VIDA report

Based on the 'Cases 2006-15' file, a second spreadsheet was created with a copy of all the cases admitted in 2015. This was named 'Cases 2015' and four new columns were added to this file: 'clinical diagnosis', 'post-mortem diagnosis', 'final diagnoses and 'final diagnosis – affected system' (see Table 2.4). Clinical and post-mortem diagnoses were established using laboratory and post-mortem reports and the case letters sent to the referring practitioners. In the cases where information was missing, the paper copy of the case file (which includes the clinical examination and TPR sheets) was consulted. The final diagnosis was deduced from both the clinical and post-mortem diagnoses and up to three terms were recorded for each animal, for example, in bovine viral diarrhoea virus (BVDV) persistently infected (PI) cases where there were no post-mortem findings, the final diagnosis was 'BVDV PI', but if the same animal had bronchopneumonia and chronic fascioliosis on post-mortem, all three diagnoses were recorded. Finally, all the final diagnoses were assigned to an affected system category following the same classification described in section 2.3.1.

'Cases 2015' spreadsheet
▪ Case number
▪ Date in
▪ Species
▪ Breed
▪ Type
▪ Age
▪ Years old
▪ Owner
▪ Farm postcode
▪ Practice
▪ Referral reason - Affected system
▪ Referral reason
▪ *Clinical diagnosis*
▪ Post-mortem diagnosis
▪ *Final diagnosis - Affected system*
▪ *Final diagnosis*

Table 2.4 Fields included in the 'Cases 2015' spreadsheet. The fields in italics were added to this new spreadsheet.

The age distribution of cattle and sheep in Scottish holdings was obtained from the 2015 Economic Report on Scottish Agriculture (The Scottish Government, 2016b) for comparison with the SCPAHFS 2015 cattle and sheep caseload age distribution.

With the aim to compare the final diagnoses reached at the SCPAHFS with the diagnoses reported in the VIDA, the latter were obtained from the 2014 report (Animal and Plant Health Agency, 2015c) which was the last report available at the time of analysing the data for this study.

2.3.3. Progression of the clinical presentation of BVDV PI cattle at the SCPAHFS in relation to the launch of the Scottish BVD Eradication Scheme

For the third study, the original MS Excel spreadsheet was searched for cases that had the terms BVD, BVD PI or mucosal disease as referral reason or post-mortem diagnosis. In addition, cases referred for pneumonia, ill thrift, diarrhoea and cerebellar hypoplasia were also identified. The paper copies of these files were searched and any cases with positive BVDV antigen results were retrieved and included in the data set. All the information included in the selected animals' case files was transferred to a relational database created with MS Office Access database (design is described in section 2.2.3.1). Only those animals that had evidence of having been tested twice for BVDV antigen, at least three weeks apart or that were tested once and had a final diagnosis of mucosal disease, were included in the final analysis. For cases admitted after 2013, if BVD results were missing from the history or case file, the Livestock Traceability EID Research BVD Lookup (ScotEID, 2016) was consulted to confirm BVD antigen results. Specific information from the BVD database was then transferred to separate MS Office Excel spreadsheets. The fields included in the spreadsheets are summarised in Table 2.5. Based on the date of admission, each case was assigned to a stage, 'pre' or 'post', in accordance with the implementation of the Scottish BVD Eradication Scheme, 'pre' (January 2006 - August 2010) or 'post' (September 2010 - December 2015).

From the clinical examination of the animals at the SCPAHFS, animals were classified as presenting alterations or not in seven different categories: cardiovascular signs, respiratory signs, diarrhoea without mucosal disease, mucosal disease, musculoskeletal abnormalities, neurological signs and ocular signs. Animals were considered to have respiratory disease when they presented with two or more of these signs: increased body temperature, harsh lung sounds, upper respiratory tract noises, nasal discharge and coughing. The diagnosis of mucosal disease was based on the presence of depression, ulceration and diarrhoea.

Signalment ▪ Case ID ▪ Case number ▪ Date admitted ▪ Stage ▪ Ear tag ▪ Breed ▪ Type (beef or dairy) ▪ Sex ▪ Date of birth ▪ Years old	**Farms** ▪ Case ID ▪ Date admitted ▪ Stage ▪ Farm postcode ▪ Postal area	**Practices** ▪ Case ID ▪ Date admitted ▪ Stage ▪ Practice name ▪ Postcode ▪ Postal area
History ▪ Case ID ▪ Date admitted ▪ Stage ▪ Farmer mentioned BVD (yes / no) ▪ Vet mentioned BVD (yes / no) ▪ Farmer has other complaints (yes / no) ▪ Farmer complaints (up to three) ▪ Vet has other complaints (yes / no) ▪ Vet complaints (up to three)	**Clinical presentation** ▪ Case ID ▪ Date admitted ▪ Stage ▪ Cardiovascular ▪ Respiratory ▪ Mucosal Disease (MD) ▪ Diarrhoea (without MD) ▪ Musculoskeletal ▪ Neurological signs ▪ Ocular disease	**PM diagnoses** ▪ Case ID ▪ Date admitted ▪ Stage ▪ PM diagnoses

Table 2.5 Summary of fields included in the spreadsheets used for the BVD Cases study.

2.3.3.1. Database creation

To facilitate the data recording and analysis for the BVD PI study a relational database was created using MS Office Access. The tables included in the database and their relationships

are summarised in Figure 2.1. The forms included in the database followed the structrure of the forms included in the paper case files (see Appendices 1 and 4 to 9). This database was also created with the aim to be potentially used as a future recording system for all the cases admitted to the SCPAHFS.

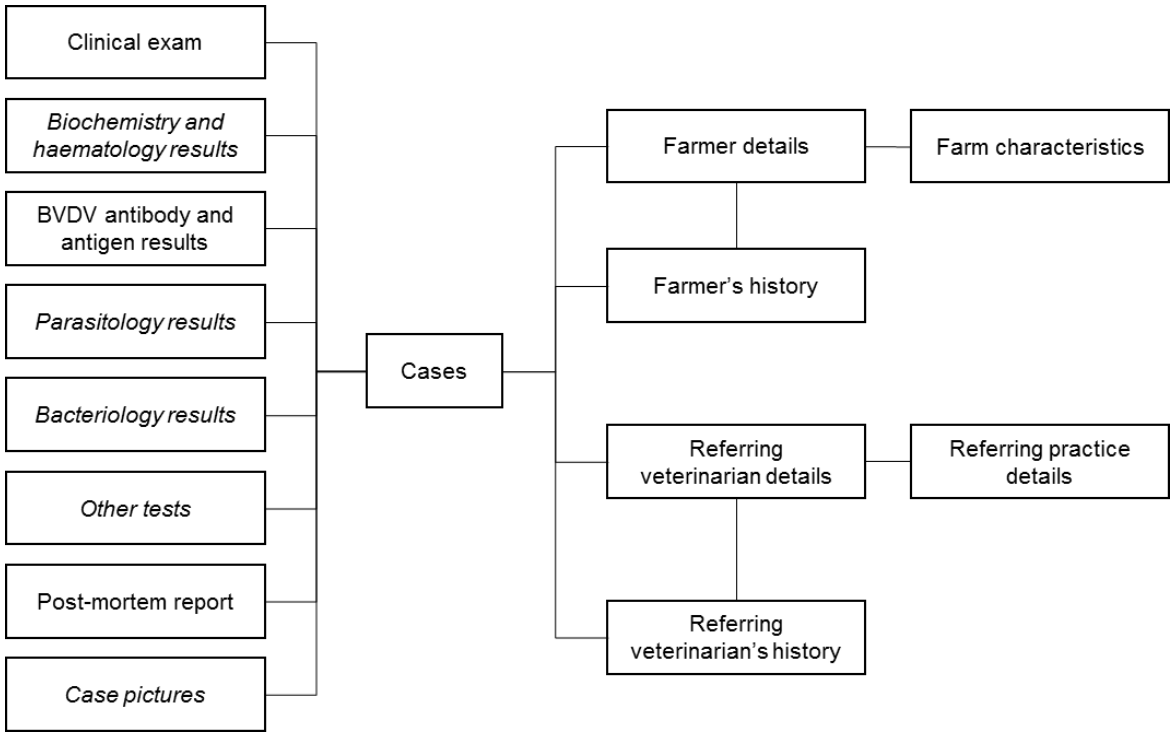


Figure 2.1 Structure of the relational database used for study presented in Chapter 5. Data in boxes with text in italics were not included in the study.

2.3.4. BVD Case Study

During the data collection for the BVD PI study, five PIs were identified that were referred from the same farm in a period of just over a year. With the aim to study this outbreak and with approval from the Ethics Committee, a meeting was arranged with the farmer. An interview draft was prepared before the meeting to facilitate the discussion. The two farmers, their first opinion veterinary surgeon and three researchers were present during the interview. Any information that needed to be clarified was discussed at a later date via telephone call. The farmer and first opinion veterinarian were given the opportunity to review the final case study.

2.4. Data analysis

2.4.1. Analysis of the SCPAHFS caseload (2006-15)

The data in this thesis were mainly analysed and presented using MS Office Excel. The total number of cases admitted to the SCPAHFS per species were compared to the mean number of cattle, sheep, pigs, goats and alpacas in Scottish holdings in June 2006-15 using a Chi-square "goodness of fit" test (Lowry, 2016). The caseload was also compared to the total number of samples submitted to the VIDA system in between 2006 and 2014 using the same test. The number of total monthly cases were divided in two periods: 2006-2011 and 2012-16 with the aim to evaluate the effect that the reorganisation of final BVMS teaching had in the number and type of admissions during the year. The age distribution of dairy and beef cattle admitted to the SCPAHFS was compared using a Chi-square test for association using Minitab (Minitab Inc., 2016).

The postal areas of the referring farms rather than full postcode were used to analyse the origin of the cases in order to protect the farms' privacy. The postal areas were located on a map created with QGIS, an open source geographic information system (QGIS, 2016). Geospatial data for the map layout (postal areas) were obtained from ShareGeo Open (DSpace, 2016). The referring practices, Scotland's Rural College (SRUC) Disease Surveillance Centres (DSC) and SCPAHFS were located on the map using their geographical coordinates, obtained by looking up their addresses on Google Maps (Google, 2016). Four separate maps were created for the total number of cases, the number of dairy, beef and sheep cases admitted to the SCPAHFS. With the aim to be able to compare the volume of cases for the different species and between chapters 3 and 4, the same thematic shading was used in the colour scale of all the maps. The distance by road between the referring veterinary practices and the SCPAHFS was calculated using Google Maps.

2.4.2. Diagnoses reached at the SCPAHFS in 2015 and comparison to the VIDA report

The data analysis in Chapter 4 was very similar to that described in the previous section. The total number of cases admitted to the SCPAHFS per species in 2015 were compared to the total number of submissions per species made to the VIDA database in 2014 using a Chi-square "goodness of fit" test using an online statistical table calculator (Lowry, 2016). The same test was used to compare the age distribution of cattle and sheep admitted to the SCPAHFS in 2015 with the age distribution of cattle and sheep in Scottish holdings in June 2015 (The Scottish Government, 2016b). In this study only one map was created, showing the location of the total cases admitted in 2015 and their referring veterinary practices. The proportion of referral reasons for cattle and sheep admitted to the SCPAHFS presented in bar graphs with error bars denoting binomial 95% confidence intervals. The same method was used to present and compare the SCPAHFS 2015 and VIDA 2014 diagnoses grouped by affected system. The individual SCPAHFS diagnoses were compared to the equivalent VIDA categories in a separate graph.

2.4.3. Progression of the clinical presentation of BVDV PI cattle at the SCPAHFS in relation to the launch of the Scottish BVD Eradication Scheme

The BVD PI case information recorded on the MS Office Access database was exported and analysed using Excel. Chi-square tests of association were used to compare the proportions of beef and dairy, male and female and age distribution of the cases admitted before and after the Scottish Government BVD eradication scheme. Maps for the total number of BVD PIs and for the number of PIs admitted before and after the start of the scheme were created using QGIS (QGIS, 2016). Given the small number of cases referred per postal area in this study, only one colour was used to indicate the areas with cases. The respective referring practices and SRUC DSC were also located on the maps.

From the history of the BVD PI cases, the number of cases where the farmer and first opinion veterinarian mentioned BVD before and after the start of the scheme were compared;

however, Chi-square tests of association were not performed since the numbers of some observations were fewer than five. The number of cases where the farmer and veterinarian reported clinical signs were compared using Chi-square tests of association and, in those cases in which signs were reported, these were compared between cases admitted before and after the start of the scheme in a clustered column graph with error bars denoting binomial 95% confidence intervals. The same methods were applied to the number of cases that presented clinical signs on the clinical examination on admission at the SCPAHFS before and after the start of the scheme and the presence of significant findings on the post-mortem examination.

3. Analysis of the SCPAHFS caseload (2006-15)

3.1. Introduction

The final report of the review of veterinary surveillance, known as 'the Kinnaird report', was published in 2011 by the Scottish Government. The document identified the need for more efficient, cost-saving approaches and recommended that surveillance should include data from additional existing animal health sources (The Scottish Government, 2011). The cases admitted to Scottish Centre for Production Animal Health and Food Safety (SCPAHFS) generate a large amount of animal health data that are used for teaching and research purposes; however, their potential as a source of surveillance intelligence has never been evaluated. In addition, although cases have been used in studies that focused on particular diseases (Clements et al., 2002; Bexiga et al., 2007; Bexiga et al., 2008), the demographics and characteristics of the SCPAHFS caseload as a whole have never been analysed. One of the aims of this thesis is to evaluate the usefulness of the SCPAHFS as an additional source of passive surveillance data. The study presented in this chapter is based on the analysis of the case details recorded on spreadsheets between 2006 and 2015 and aims to present the characteristics and demographics of the SCPAHFS caseload to perform a first evaluation of its potential usefulness as a source of surveillance intelligence. At the same time, the results of this analysis can be used as a background for future studies based on the SCPAHFS caseload.

3.2. Results

3.2.1. Number of cases

A total of 1,727 cases were admitted to the SCPAHFS between 1st January 2006 and 31st December 2015; a mean number of 173 animals per year. Figure 3.1 shows the total number of cases. Cattle represented the majority of the caseload (64%) and were divided in 53%

dairy (594 animals, 34% of total cases) and 47% beef (510 animals, 30% of total cases). No poultry admissions were recorded on the Excel spreadsheets. The species distribution of the SCPAHFS caseload was significantly different ($p < 0.05$) from the mean distribution of cattle, sheep, pigs, goats and alpacas in Scottish holdings during 2006-15 (June census) – where sheep represent 76% of the population (Figure 3.2); and it also differed from the total number of samples submitted per species to the VIDA database from 2006 to 2014 (Figure 3.3), with more sheep being admitted to the SCPAHFS ($p < 0.005$).

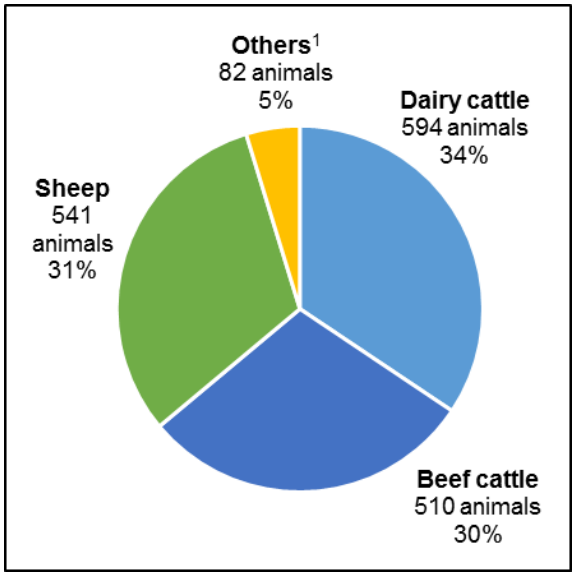


Figure 3.1 Number of cases admitted to the SCPAHFS between 2006 and 2015 (percentage of total caseload shown below the actual number). [1]Includes pigs, goats and alpacas.

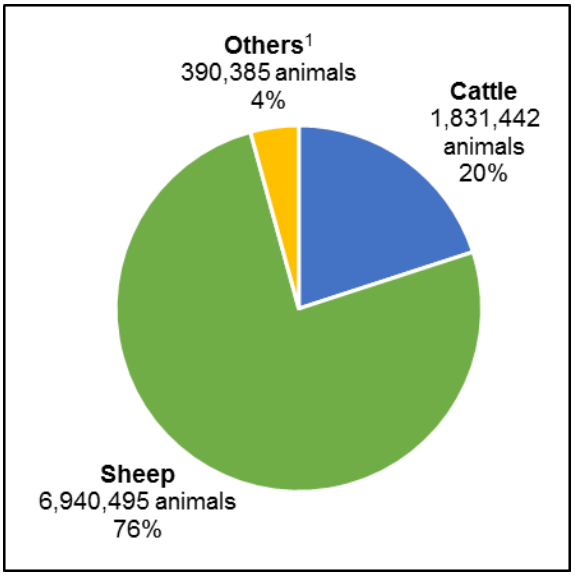


Figure 3.2 Mean number of livestock in Scottish holdings in between June 2006 and 2015 (The Scottish Government, 2016b). [1]Includes pigs, goats and alpacas.

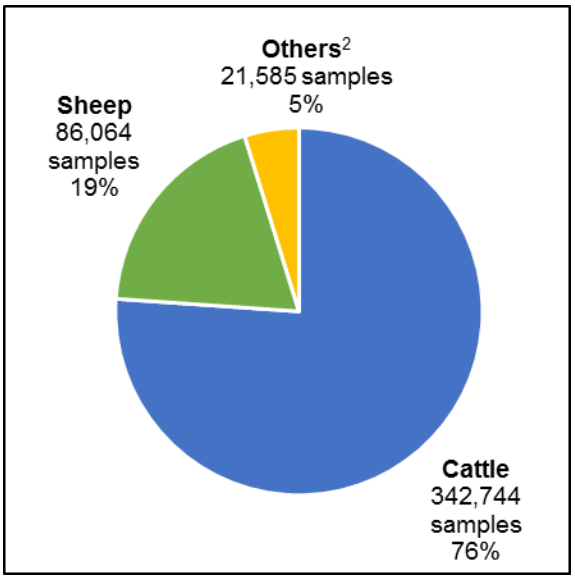


Figure 3.3 Number of samples submitted to the VIDA system between 2006 and 2014 (Animal and Plant Health Agency, 2014c; Animal and Plant Health Agency, 2015c). [2]Includes pigs and goats.

Figure 3.5 represents the number of cases admitted to the SCPAHFS per species and year. The year with fewest cases was 2012, with 113 animals admitted and, since 2013, there has been an increase in the number of annual admissions, with 227 and 228 animals being admitted in 2014 and 2015 respectively.

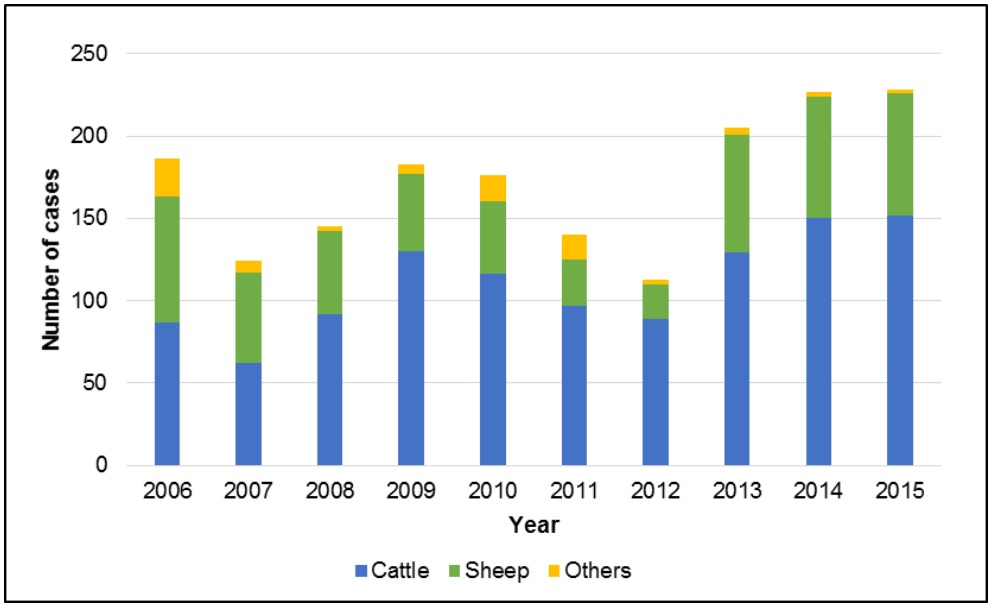


Figure 3.4 Total number of cases admitted to the SCPAHFS per year and species.

The monthly trends for the total number of cases admitted each year are shown in Figures 3.5 and 3.6. During 2006-11 there was a marked decrease in the number of cases in summer, with most years having no cases at all in July. This was followed by a peak of cases in October. From 2012 to 15 the admissions were more constant during the year, with cases being admitted in every month.

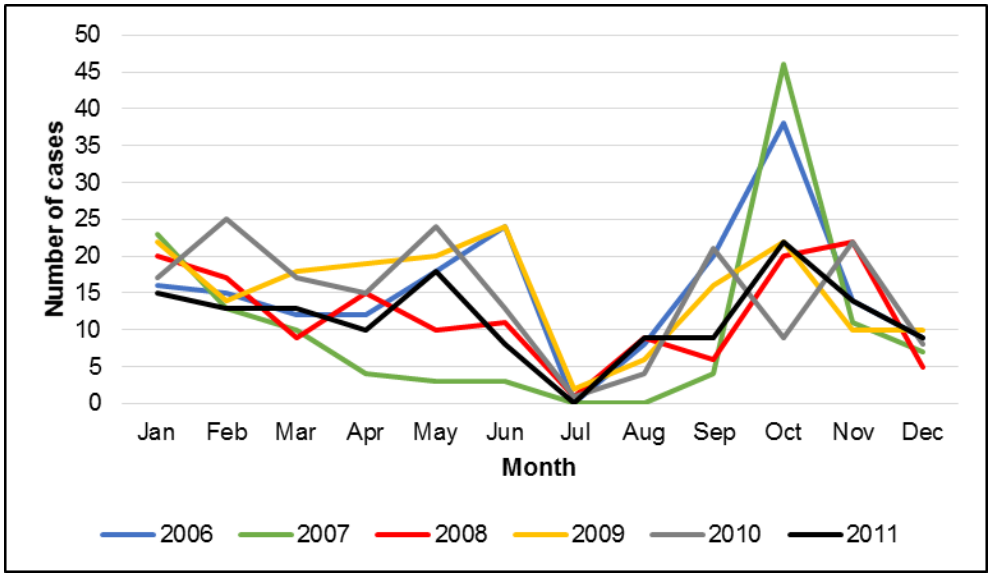


Figure 3.5 Number of cases admitted to the SCPAHFS per month between 2006 and 2011.

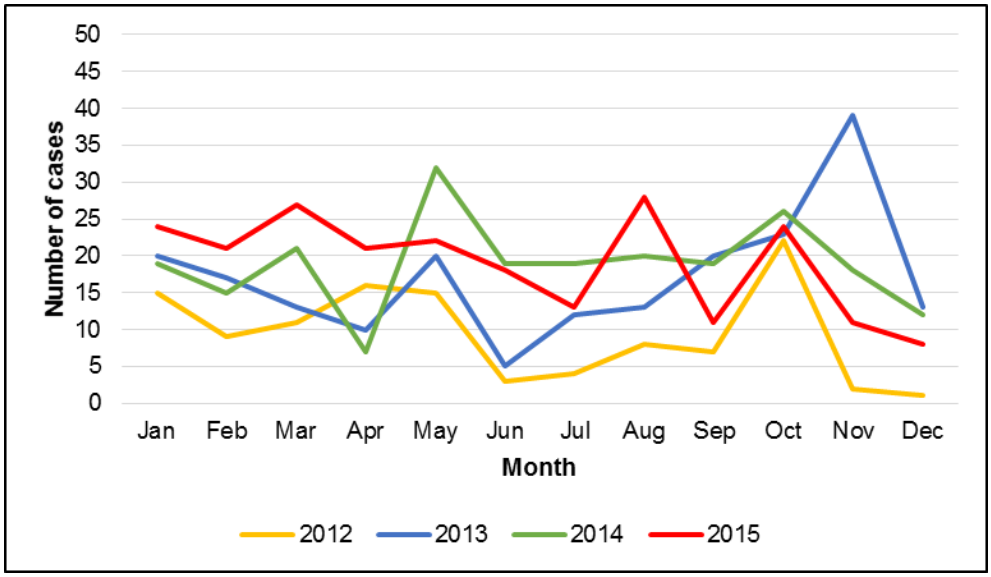


Figure 3.6 Number of cases admitted to the SCPAHFS per month between 2012 and 2016.

3.2.2. Age distribution

The age distribution of the animals admitted to the SCPAHFS in 2006-15 are represented in Figures 3.7 and 3.8 total cattle and sheep and Figures 3.9 and 3.10 for dairy and beef cattle, respectively. There was a significant difference (Chi-square test, p = 0.000) between the age distributions of dairy and beef cattle, as the distribution of dairy cases was significantly older than beef cases. In both graphs there was a total of 2-3% of animals without an age recorded in the Excel spreadsheet. In the case of sheep, 19% of the animals did not have a recorded age and the majority of the caseload was over a year old (62%).

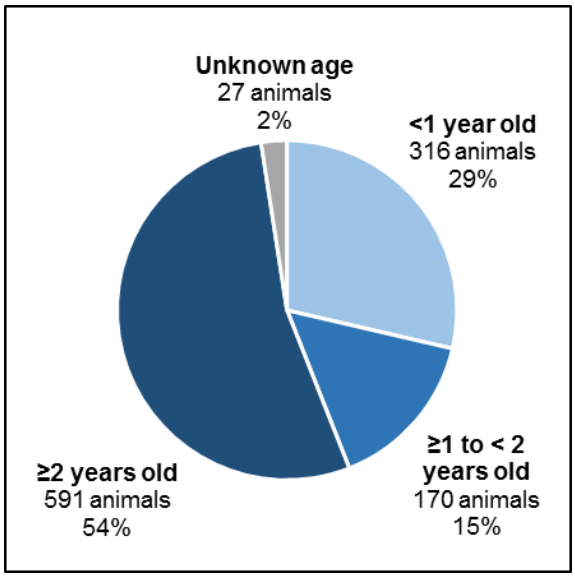


Figure 3.7 Age distribution of cattle admitted to the SCPAHFS (2006-15).

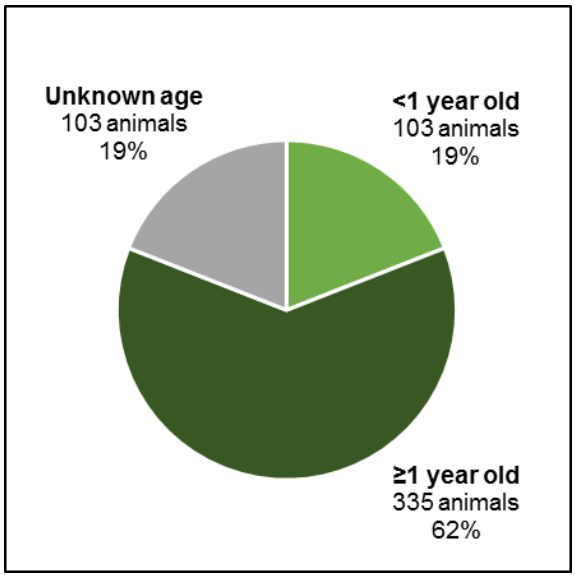


Figure 3.8 Age distribution of sheep admitted to the SCPAHFS (2006-15).

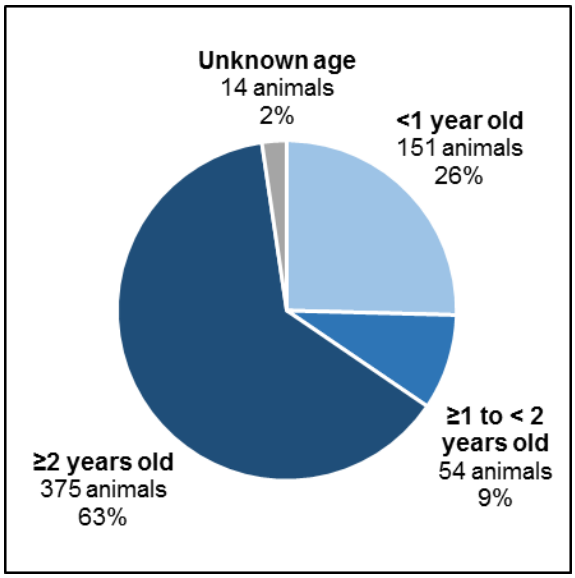


Figure 3.9 Age distribution of dairy cattle admitted to the SCPAHFS (2006-15).

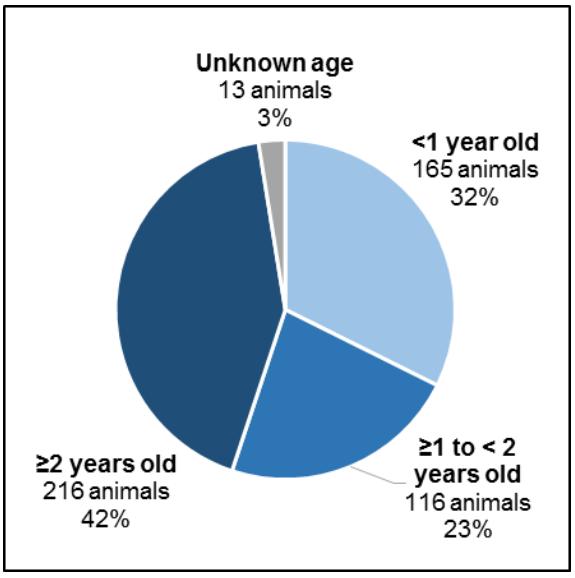


Figure 3.10 Age distribution of beef cattle admitted to the SCPAHFS (2006-15).

3.2.3. Origin of the cases

A total of 77 different veterinary practices and 591 farms referred cases to the SCPAHFS between 2006 and 2015. Figure 3.11 shows the number of farms and practices that referred cases each year. While the number of referring practices remained more or less stable during the ten years included in this study (between 20 and 30 practices a year), there has been a progressive increase in the number of referring farms since 2006, with only two decreases in 2007 and 2011-12. The farms were located in 16 postal areas of Scotland (13 areas), Northern England (two areas) and Northern Ireland (one area). Figures 3.13 to 16 show the number of total, dairy cattle, beef cattle and sheep cases admitted per postal area (Northern Ireland case not shown) and the location of the respective referring practices. The eight Scotland's Rural College Disease Surveillance Centres (DSC) are also shown on the map. A total of 219 cases did not have a referring practice recorded. The postcodes of eight farms, corresponding to nine cases and the location of ten veterinary practices could not be identified. The majority of cases originated from Central and South-West Scotland, being the postal areas closest to the SCPAHFS, G, ML, PA and KA, the ones that presented the highest number of cases with over 250 animals referred per area during the ten-year period. The higher concentration of cases coincided with the presence of more referring practices in the same postal area. When looking at the individual maps for dairy cattle, beef cattle and

sheep, the concentration of cases around the SCPAHFS is clearer, especially in the case of sheep. Over 100 sheep were received from G, ML, PA and KA, and less than 20 cases were referred from each of the remaining postal areas. In relation to the DSC, the SCPAHFS caseload overlapped with the areas covered by the Ayr and Dumfries centres, with 254 and 172 cases received from KA and Dumfries (DG), respectively.

Regarding the number of cases referred per practice in relation to the distance to the SCPAHFS (Figure 3.12), although all the practices that referred more than 50 cases during 2006-15 were located under 100 km from the SCPAHFS, there was not a clear relationship between distance and number of cases. Many practices under 50 km from Glasgow referred less than 25 cases during the ten-year period, whereas a practice located over 150 km from Glasgow referred 46 cases. The mean number of cases referred per practice was 27.

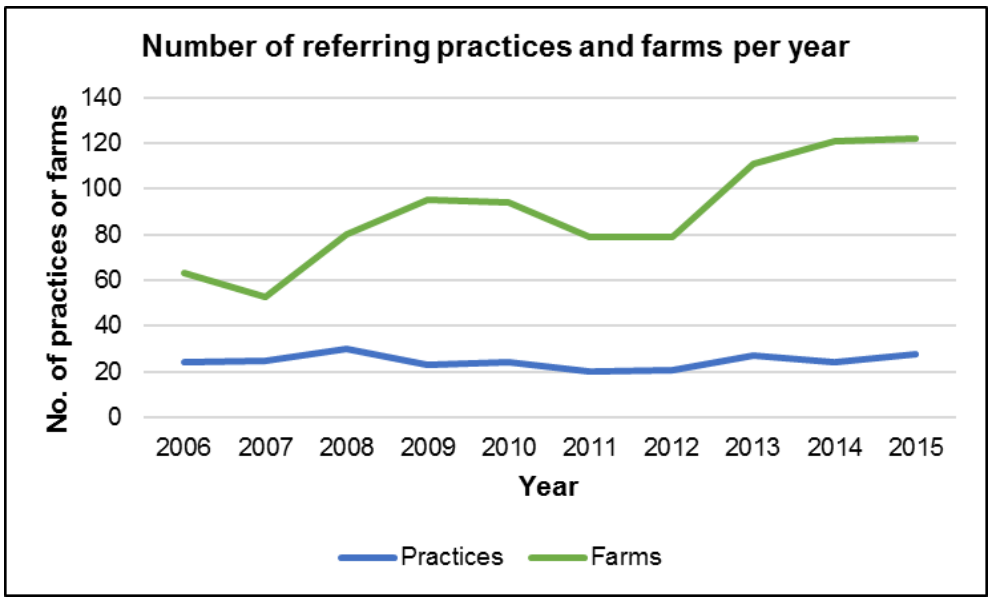


Figure 3.11 Number of referring veterinary practices and farms per year.

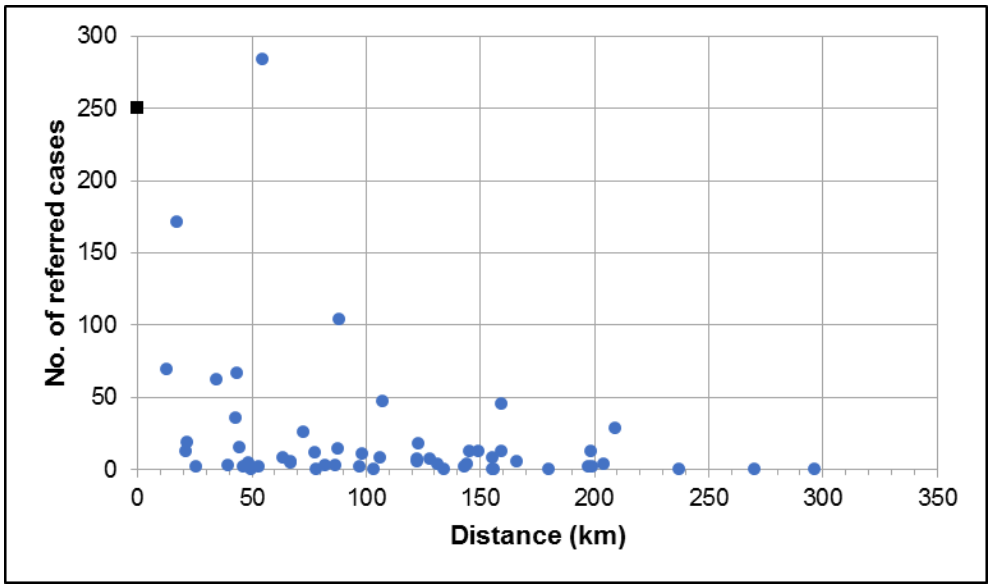


Figure 3.12 Number of cases referred per practice between 2006 and 2015 in relation to the distance by road to the SCPAHFS. The black square represents the SCPAHFS (0 km distance), whose own clinicians referred 250 animals.

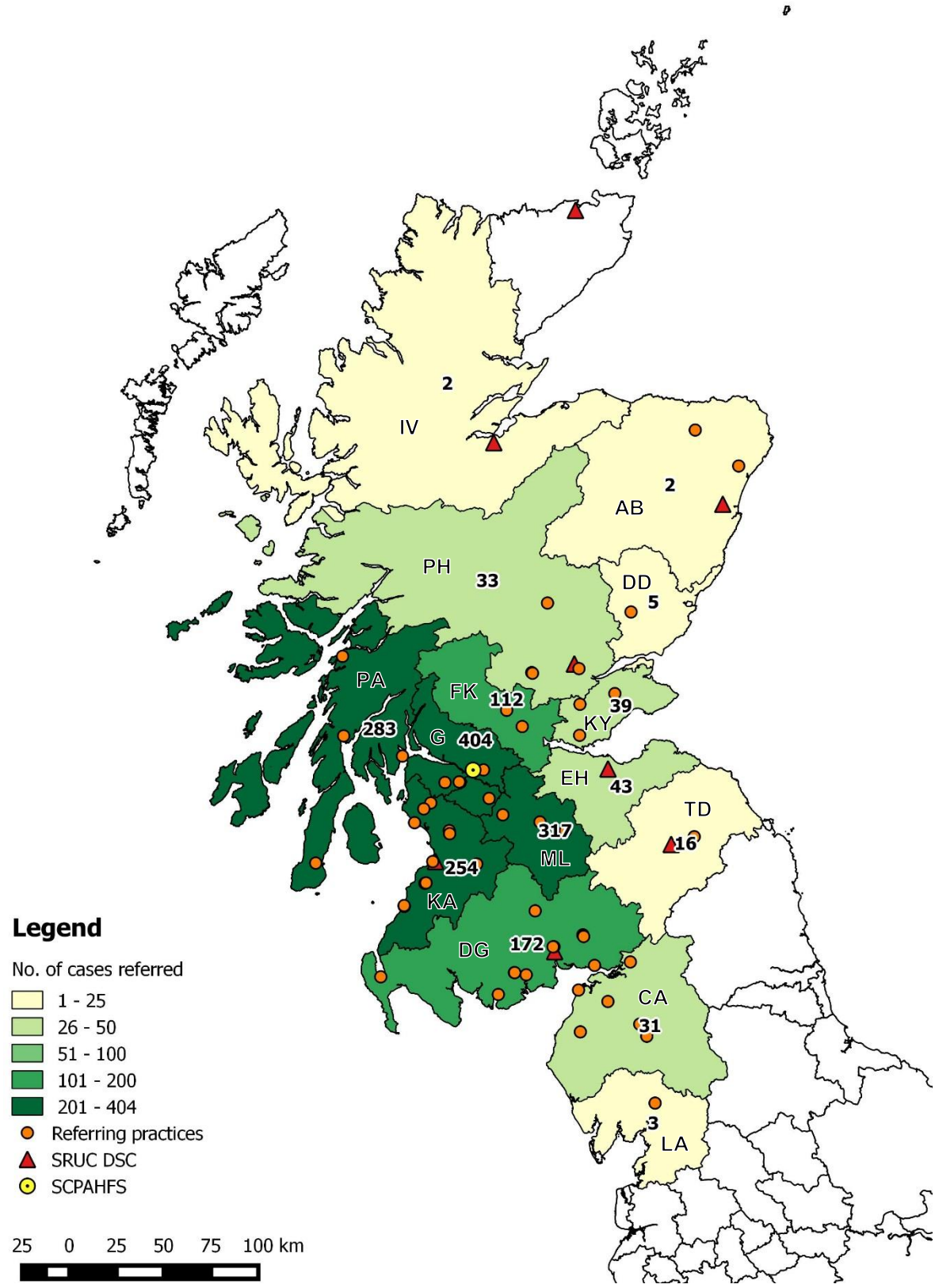


Figure 3.13 Total number of cases referred per postal area (2006-15) and location of the referring veterinary practices and SRUC DSC.

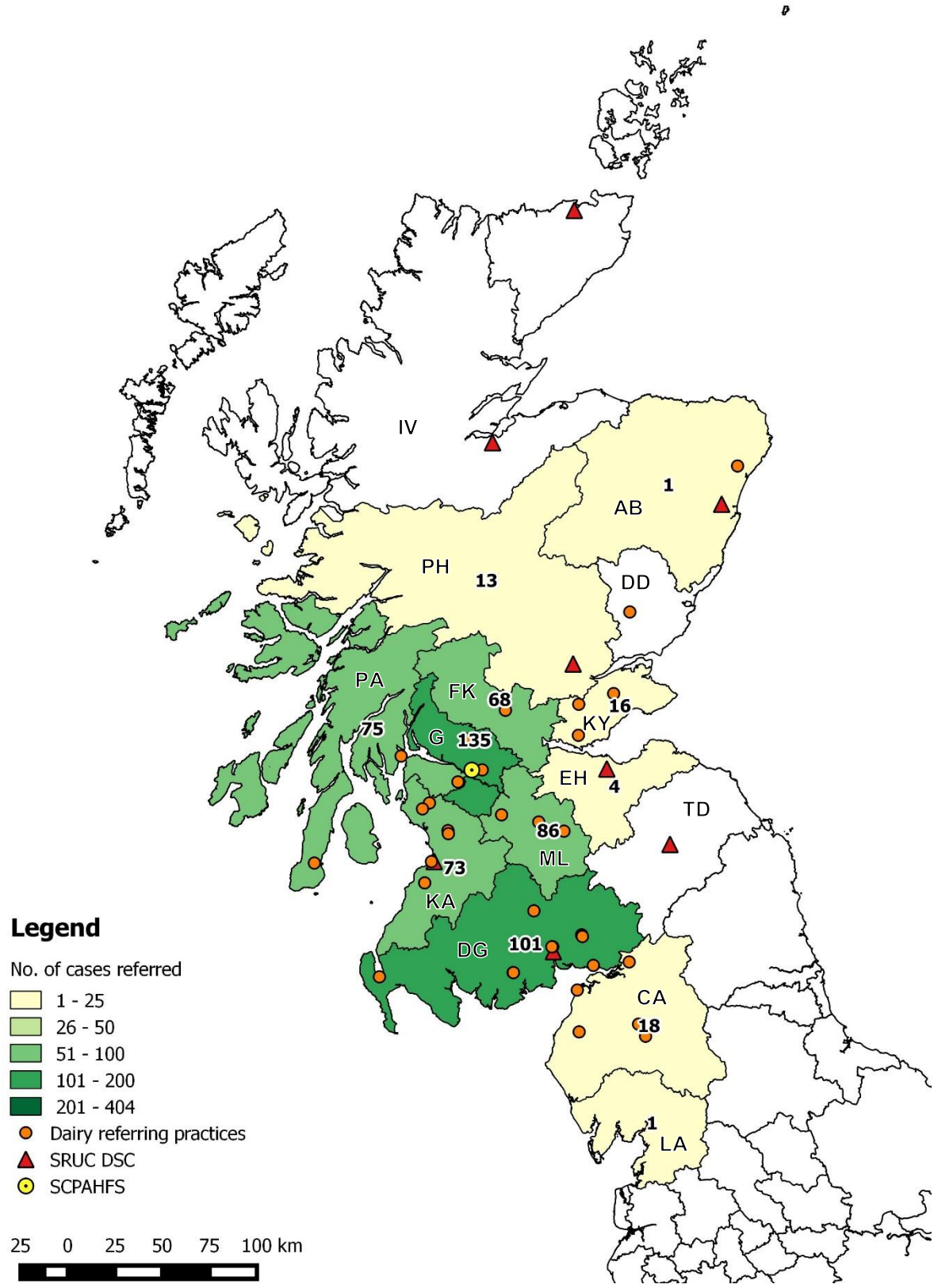


Figure 3.14 Dairy cattle referred per postal area (2006-15) and location of their referring veterinary practices and SRUC DSC.

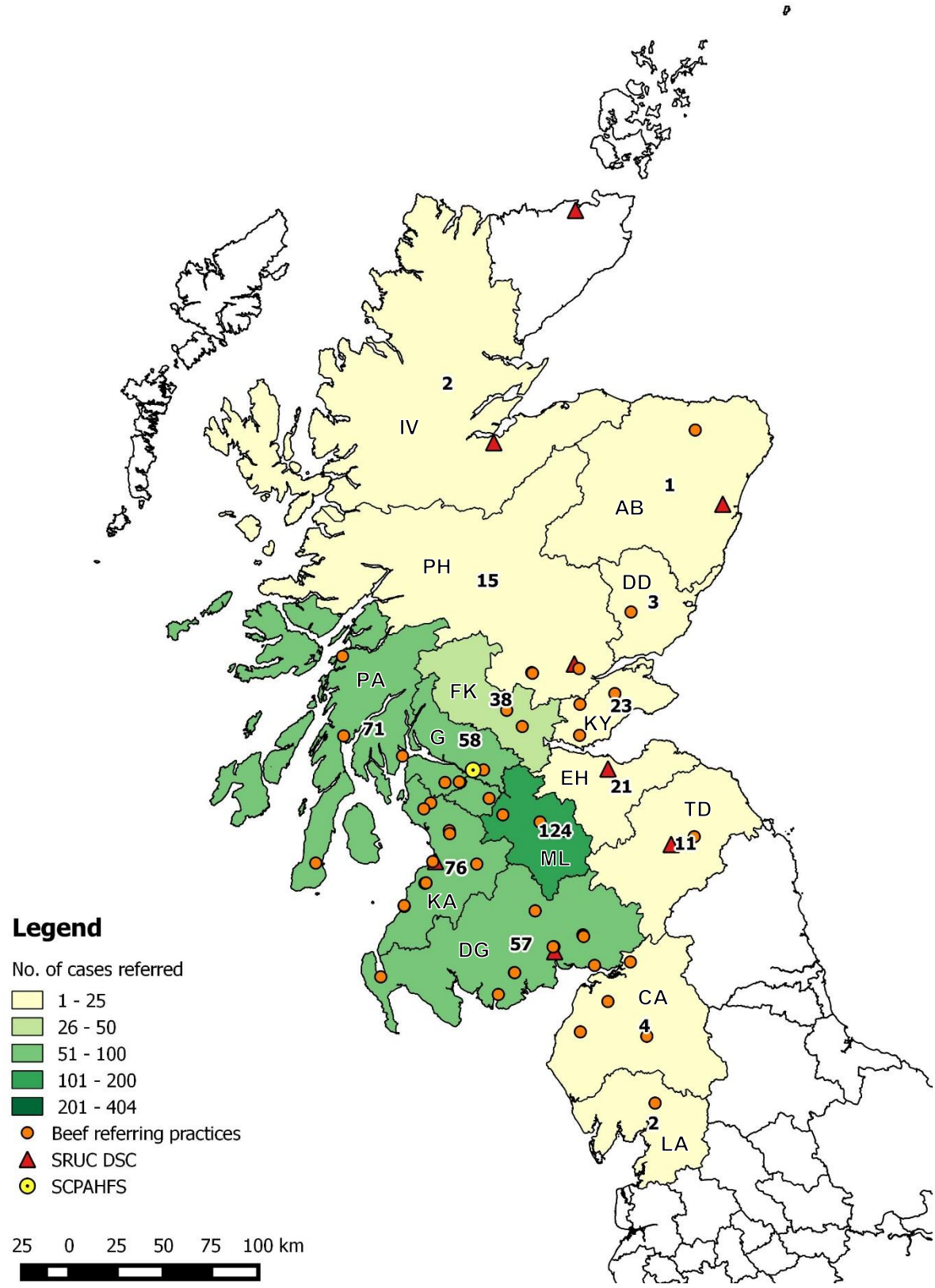


Figure 3.15 Beef cattle referred per postal area (2006-15) and location of their referring veterinary practices and SRUC DSC.

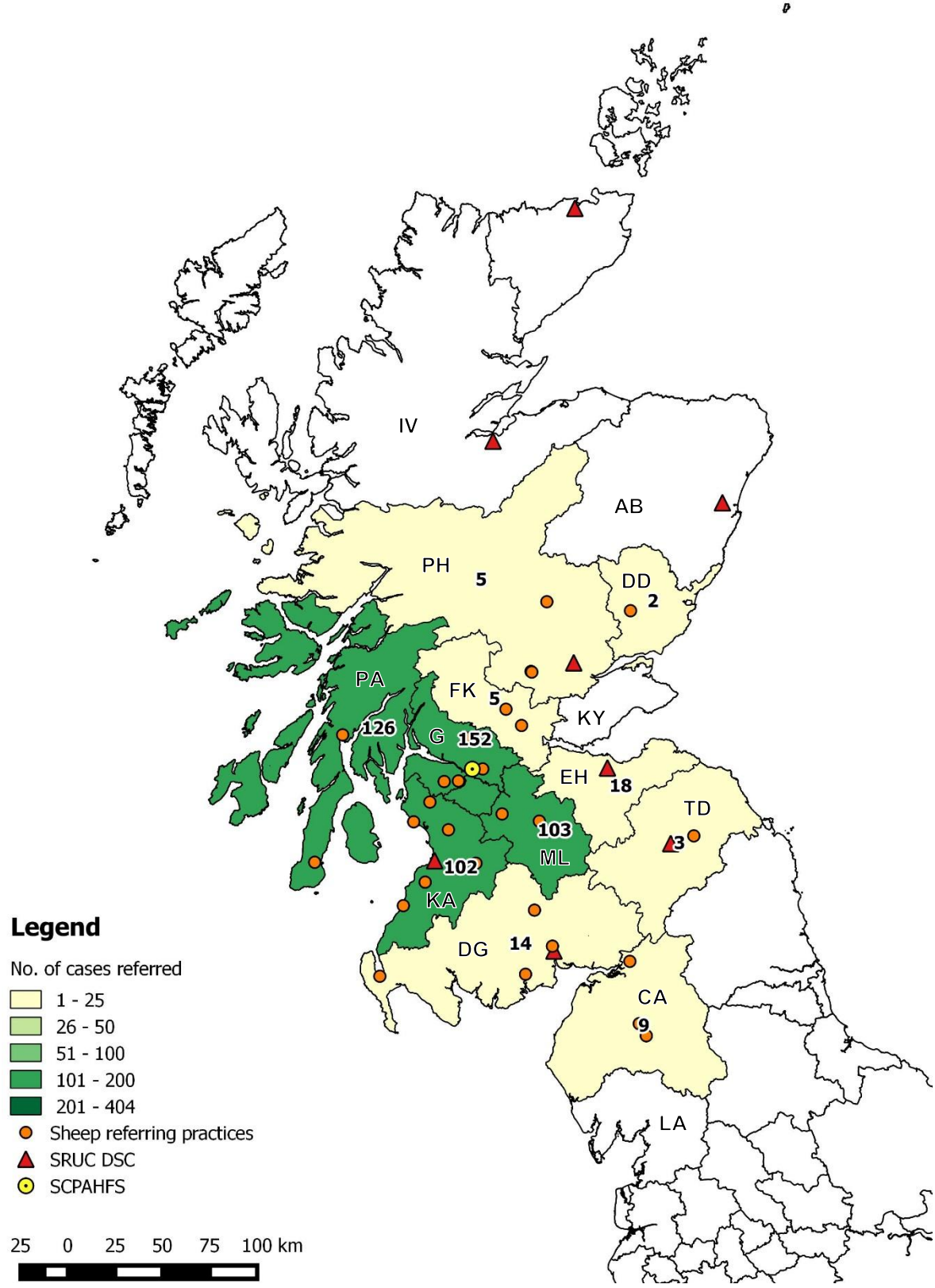


Figure 3.16 Sheep referred per postal area (2006-15) and location of their referring veterinary practices and SRUC DSC.

3.2.4. Referral reasons

The proportions of referral reasons grouped by affected systems for both cattle and sheep are summarised in Figure 3.15. Overall, the distribution of affected systems was similar between both species, with some differences. In the case of cattle, diseases of the digestive system were the most common reason for referral, with 35% of the referred animals being affected (391 animals). Systemic diseases were in second place, being the referral reason of 20% of the cases (225 animals), and respiratory diseases were third presenting in 13% of the cases (142 animals). These were followed by diseases of the circulatory and poietic system (12%, 130 animals) and musculoskeletal diseases (11%, 122 animals). Neurological (6%, 65 animals), reproductive (5%, 55 animals), urinary (3%, 33 animals) and skin diseases (2%, 17 animals) individually represented less than 10% of the cattle referral reasons. Only 1% of the cattle were referred without a diagnosis (11 animals) and 4% were admitted without clinical problems (49 animals). In the spreadsheet, 3% of cattle were missing a referral reason (30 animals).

Digestive disease was also the first referral reason of the SCPAHFS sheep caseload with 24% of the cases (128 animals). Respiratory disease was the second most common condition with 20% of affected animals (107 animals), followed by systemic disease (17%, 90 animals) and musculoskeletal problems (11%, 57 animals). Reproductive (9%, 49 animals) and neurological (8%, 48 animals) disease were less important, and only 11 sheep were presented with skin (1%, 6 animals) and circulatory (1%, 5 animals) problems. No sheep were admitted for urinary disease. Healthy animals represented a larger proportion of the sheep caseload than they did in cattle, with 12% of sheep being admitted without a clinical problem (65 animals); and 1% did not have a final diagnosis (7 animals). The proportion of cases that were missing a referral reason in the Excel spreadsheet was also larger than cattle with 5% of the cases without a recorded reason (26 animals).

When looking into the individual referral reasons (Table 3.1), alterations of body weight and/or size (e.g. ill thrift, stunted growth, weight loss) and pneumonia were the main reason for referral of cases to the SCPAHFS with a total of 164 and 147 affected animals respectively (9% of the total caseload for both categories). These were followed by Johne's disease, which was an important condition in both cattle (97 animals) and sheep (41 animals)

and represented 8% of the total caseload. Ovine pulmonary adenocarcinoma (OPA) was the referral reason of 83 sheep cases, 5% of the total caseload. Dental or mandibular problems were also an important condition in sheep (70 animals) compared to cattle (3 animals). The rest of referral reasons represented less than 5% of the total 2006-15 SCPAHFS caseload. A table with the full list of individual referral reasons is presented in Appendix 10.

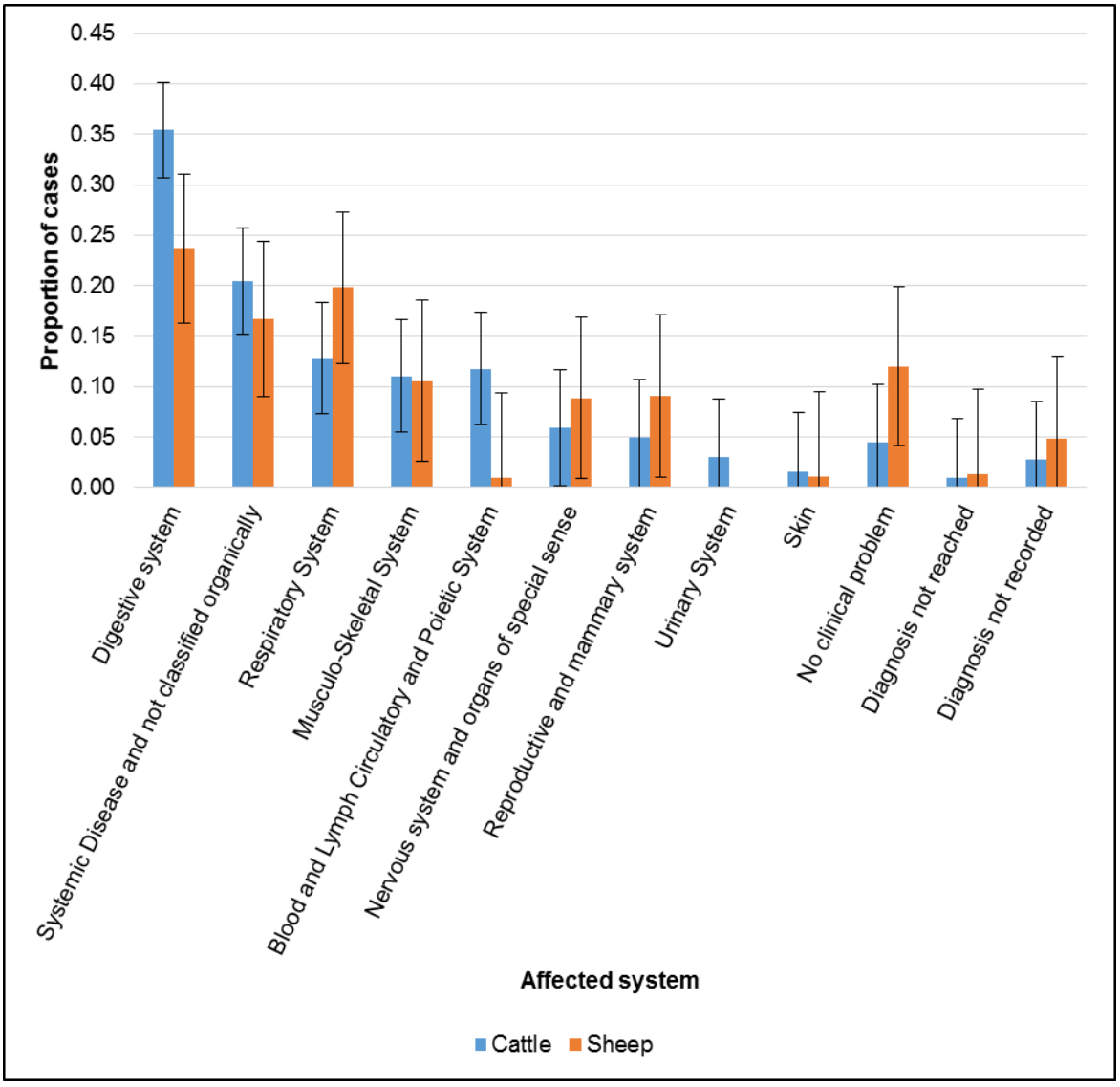


Figure 3.17 Cattle and sheep referral reasons grouped by affected system as per the VIDA categories. Error bars denote binomial 95% confidence limits.

Referral reason	Cattle	Sheep	Others[1]	Total	Total %[2]
Alterations of body weight and/or size	97	65	2	164	9
Pneumonia	124	14	9	147	9
Johne's disease	97	41	0	138	8
OPA	0	83	0	83	5
Dental/mandibular abnormalities	3	70	0	73	4
Healthy animal	25	29	18	72	4
Diagnosis not recorded	30	26	10	66	4
BVD PI	64	0	0	64	4
Diarrhoea	56	4	2	62	4
Cull animal	6	36	11	53	3
Displaced abomasum	51	0	0	51	3
Lameness	26	19	0	45	3
Pericarditis	43	0	0	43	2
Mastitis	21	19	0	40	2
Arthritis / Polyarthritis	18	17	3	38	2
Congenital abnormalities	31	5	1	37	2
Neurological deficits	18	16	2	36	2
Peritonitis	29	1	0	30	2
Endocarditis	26	1	0	27	2
Others[3]	505	142	30	677	39
Total	**1,270**	**588**	**88**	**1,946**	**113**

Table 3.1 Individual referral reasons per species. [1]Includes pigs, goats and alpacas. [2]Over a total of 1,727 cases. Some animals presented with more than one referral reason, therefore the total percentage adds up to more than 100%. [3]Conditions that represented less than 1% of the total cases were grouped under 'Others'.

3.3. Discussion

This study was designed to analyse and describe the demographics and referral reasons of the 2006-15 SCPAHFS caseload, with the aim to provide a first evaluation of its suitability as an additional source of surveillance data. Data were available for summary and analysis from a substantial number of farm animals (1,727), predominantly cattle and sheep in South West and Central Scotland. The summary provides an interesting insight into the crude breakdown of health problems causing chronic conditions affecting economic productivity in cattle and sheep. The caseload covered an extensive area in Scotland and North West

England and overlapped with the DSC in Ayr and Dumfries, suggesting that the SCPAHFS could complement the surveillance activities in these areas.

The study was based on the analysis of data recorded in a spreadsheet where many fields were missing and the existing records required a considerable amount of data cleaning. Currently, case information at SCPAHFS is recorded in three different locations, in different formats: a spreadsheet, paper case files and electronic case folders. The records are not integrated and none of the platforms collated all the information (e.g. the daily progression of the cases is only recorded on the cases' paper file). A considerable amount of data are recorded at the SCPAHFS; however, these are not readily accessible. There may be some inaccuracies in the data presented in this study resulting from cases not recorded in the spreadsheet. In addition, although the spreadsheet includes a field to record post-mortem diagnoses, these were missing in more than 50% of the caseload, which is the reason why these were not analysed in this study. Another inconvenience was the lack of standardisation of the referral reasons that were recorded in a free-text field and included both clinical signs and diagnoses. For this thesis, these were grouped under the body system groups included in the VIDA report (Animal and Plant Health Agency, 2015c); however, the individual VIDA codes only include diagnoses and comparison between VIDA and the results of this study was not possible.

To the author's knowledge there are no previous reports of caseloads received by farm animal veterinary teaching hospitals and there is little literature about the most common conditions diagnosed by first opinion farm animal practitioners. A survey published by the University of Nottingham in 2014, in which UK practitioners were asked what were the three most frequently seen conditions, found that reproductive disease was the most common condition both cattle and sheep were examined for, followed by respiratory, non-specific and musculoskeletal conditions (Nielsen et al., 2014). In Sweden, an analysis of data from the dairy industry cattle database also identified reproductive disorders as the most frequent (e.g. mastitis, puerperal paresis, retained placenta), followed by respiratory disease and gastrointestinal disorders (Mörk et al., 2009). Reproductive disease cases are usually dealt with by first opinion veterinary practitioners and treated on farm and are therefore rarely referred to the SCPAHFS (less than 10% of cases in cattle and sheep). However, both references highlighted digestive, respiratory and systemic diseases as important conditions

of cattle and sheep. These findings agree with the most common referral reasons presented by the SCPAHFS caseload.

A degree of bias is always associated with any source of passive surveillance data, especially when these are not primarily obtained for surveillance purposes. Farm animal veterinary hospitals that receive animals that may be treated and sent back to the farm of origin are likely to receive higher proportions of specialised cases. Cases that are considered valuable enough to justify the expense of the treatment may also be over represented (Bartlett et al., 2010). By contrast, the SCPAHFS relies on donated cases that do not return to the farm and, therefore, most animals are affected by chronic and endemic conditions, as shown by the results of this study. The literature suggests that the referral of cases or submission of samples to diagnostic laboratories is affected by the farm distance to the centre (Watson et al., 2008; Bartlett et al., 2010). This was also the case at the SCPAHFS, where the origin of the cases was dictated by the proximity to the centre, even though the free collection service is offered to all farmers regardless of their location. The relationship between first opinion veterinarians and laboratories has also been highlighted as an important component to ensure the quality of surveillance data (Robinson et al., 2012; The Scottish Government, 2011). At the SCPAHFS, practices that have a closer relationship with the centre have referred the most cases over the ten years – e.g. practitioners involved in Bachelor of Veterinary Medicine and Surgery (BVMS) teaching, practices where SCPAHFS staff have worked previously and *vice versa*. The feedback provided to the farmer and referring veterinarian by phone call and the summary letter also help to sustain these relationships.

The denominator data for the total animal population at risk of disease, from which these cases were referred, is unknown. Furthermore, it is unknown what proportion of similar cases are not referred; therefore, estimation of the total burden of disease in the population is not possible with these data, though this also applies to VIDA and other surveillance data.

In addition to the inevitable bias, surveillance data obtained from secondary sources is commonly affected by poor data completeness. This was the case in the recording in the National dairy databases used by the Scandinavian countries, where the usefulness of the data recorded in the systems in the different countries was poor due to data incompleteness (Lind et al., 2012). As discussed above, the SCPAHFS is affected by both factors. Although

a considerable amount of data are recorded at the centre, these are not readily available for analysis due to the different formats of recording.

To summarise, this study highlighted the chronic and uneconomic nature of the cases received at the SCPAHFS, based on the referral reasons given by first opinion practitioners. Due to data incompleteness, the final diagnoses for the 2006-15 caseload were not analysed. It was therefore decided to perform a more detailed analysis of the 2015 caseload, as it was the most complete dataset. The results of this study are presented in Chapter 5 and include the final diagnoses reached at the SCPAHFS during that year. The latter are compared to the VIDA report, with the aim to allow a better evaluation of the potential usefulness of the SCPAHFS as an additional source of surveillance data.

4. Diagnoses reached at the SCPAHFS in 2015

4.1. Introduction

The main source of passive animal health surveillance in the United Kingdom is the post-mortem (PM) examinations carried out at disease surveillance centres (DSC) and veterinary investigation (VI) laboratories. The latter are collated in the Veterinary Investigation Diagnosis Analysis (VIDA) database. The previous chapter has presented the characteristics of animals admitted to the SCPAHFS between 2006 and 2015. However, it has not analysed data regarding the diagnoses reached at the centre during the ten-year period. The aim of this study was to describe in more detail the demographics and diagnoses of the 2015 caseload and to compare the data to VIDA information so assess if the SCPAHFS could be useful as a complementary source of information for passive surveillance.

4.2. Results

4.2.1. Number of cases

A total of 228 animals were referred to the SCPAHFS in 2015. The total number of cases admitted per species is shown in Figure 4.1. Only cattle, sheep and alpacas were admitted in 2015, and the proportions were different from the total SCPAHFS 2006-15 caseload (Figure 3.1, $p < 0.05$). When compared to the samples submitted per species to the VIDA database in 2014 (Figure 4.2) the distribution was also different ($p < 0.05$), with more cattle and other cases and fewer sheep in the VIDA database.

Figure 4.3 shows the monthly admissions for cattle, sheep and total cases in 2015. Overall, March, August and October were the months with the most cases, with 27, 28 and 24 animals admitted respectively, whilst the months with the fewest cases were July, September and December, when only 13, 11 and 8 animals were admitted.

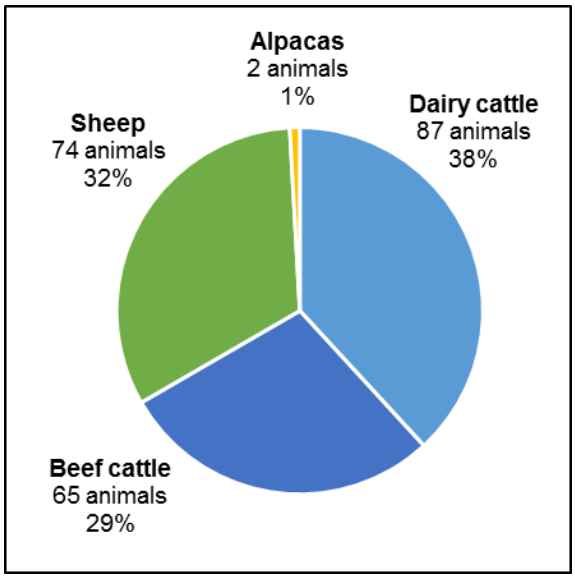


Figure 4.1 Number of cases admitted to the SCPAHFS in 2015.

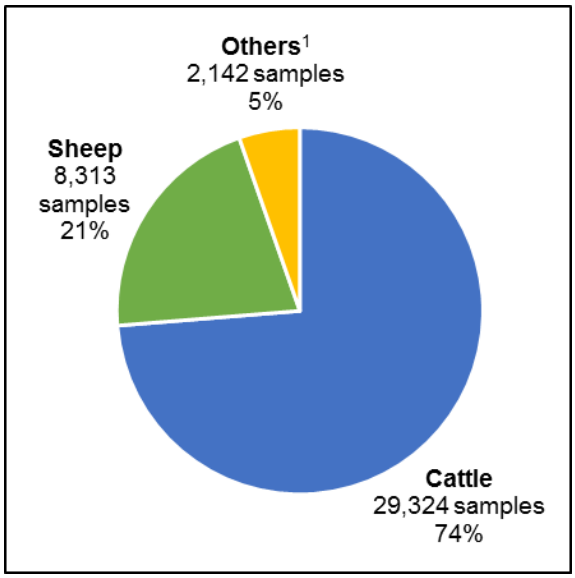


Figure 4.2 Number of samples submitted to the VIDA database in 2014 (Animal and Plant Health Agency, 2015c). [1]Includes pigs and goats.

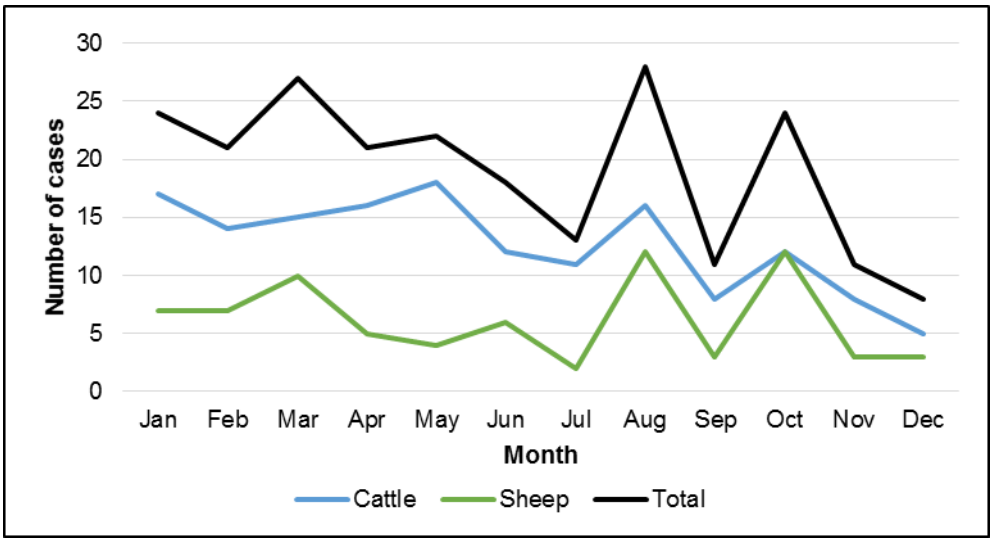


Figure 4.3 Monthly cases admitted to the SCPAHFS in 2015.

Figures 4.4 and 4.5 show the age distributions of the 2015 SCPAHFS cattle caseload and the 2015 Scottish cattle population, respectively. Cattle admitted to the SCPAHFS during 2015 were younger than the overall age distribution of the 2006-15 cattle caseload (Chi-square test, $p = 0.042$). When compared using a Chi-square "goodness of fit" test, the age distribution of the SCPAHFS cattle differed from the Scottish 2015 cattle population (Chi-square test, $p = 0.0003$). As observed with the overall 2006-15 caseload, the age distribution for dairy cattle was significantly older than the age distribution of beef cattle (Chi-square test, $p = 0.011$), as shown in Figures 4.6 and 4.7. In 2015 the age distribution of sheep

admitted to the SCPAHFS (Figure 4.8) was significantly younger than the overall 2006-15 sheep age distribution (Figure 3.9, Chi-square test, p = 0.003), however it did not differ from the age distribution of sheep in Scottish holdings in June 2015 when considering those animals with a known age (Figure 4.9, Chi-square test, p = 0.1859).

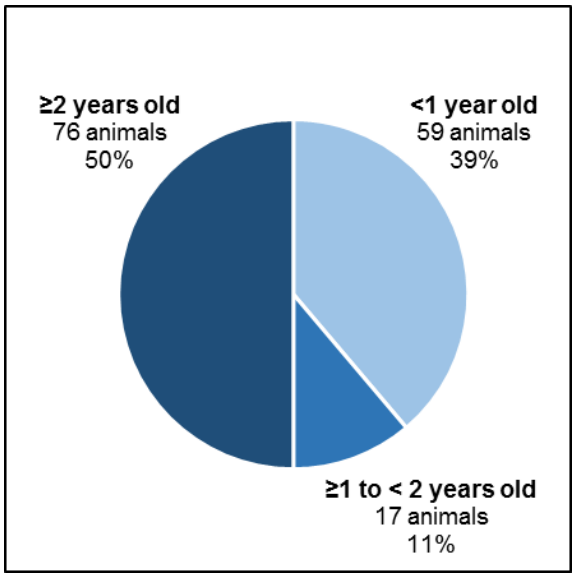


Figure 4.4 Age distribution of the 2015 SCPAHFS cattle caseload

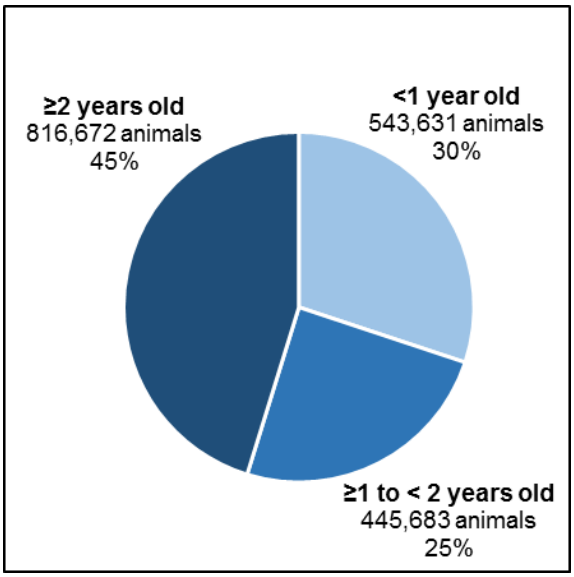


Figure 4.5 Age distribution of cattle in Scottish holdings in June 2015 (The Scottish Government, 2016b).

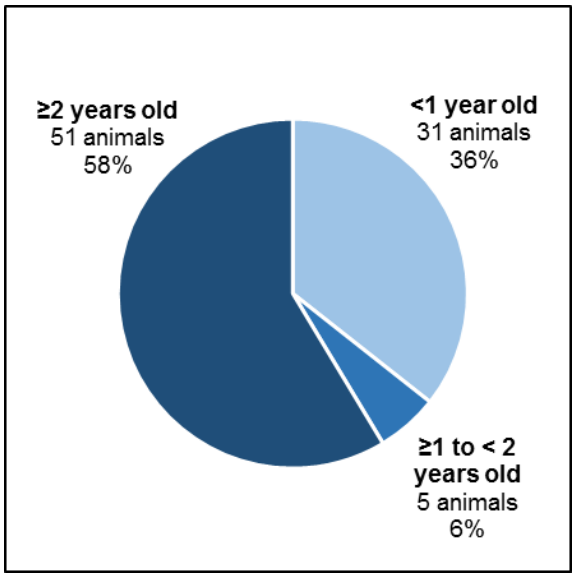


Figure 4.6 Age distribution of dairy cattle admitted to the SCPAHFS in 2015.

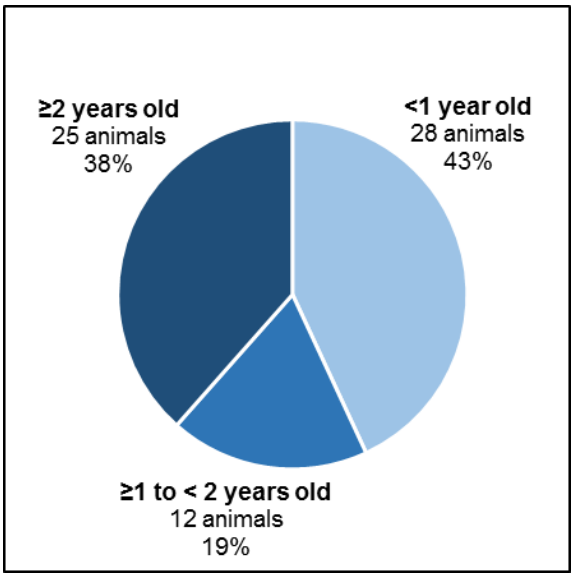


Figure 4.7 Age distribution of beef cattle admitted to the SCPAHFS in 2015.

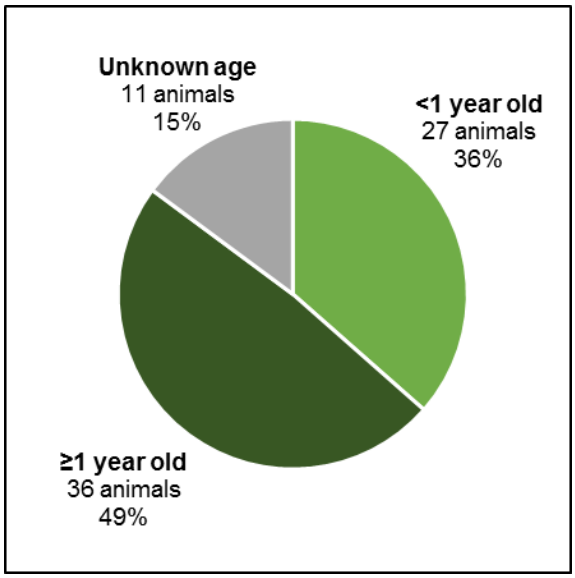


Figure 4.8 Age distribution of sheep admitted to the SCPAHFS in 2015.

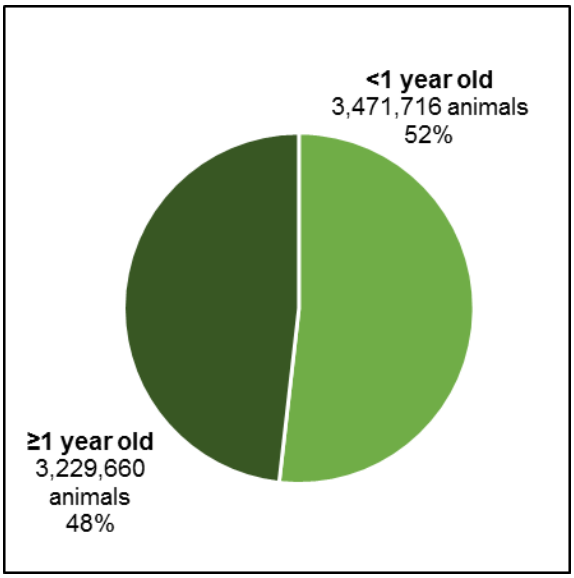


Figure 4.9 Age distribution of sheep in Scottish holdings in June 2015 (The Scottish Government, 2016b)**.**

4.2.2. Origin of the cases

The cases admitted in 2015 originated from 121 different farms and were referred from 29 veterinary practices. The farms were located in 10 postal areas in Scotland and Northern England (Figure 4.10) and 3 postcodes, corresponding to 4 cases, were missing. During 2015 the postal areas with more referred cases were G (47 animals), ML (45 animals), DG (34 animals) and PA (28 animals). In comparison to the overall 2006-15 caseload less cases were admitted from KA (23 animals). Therefore there was less overlap with the area covered by the DSC in Ayr.

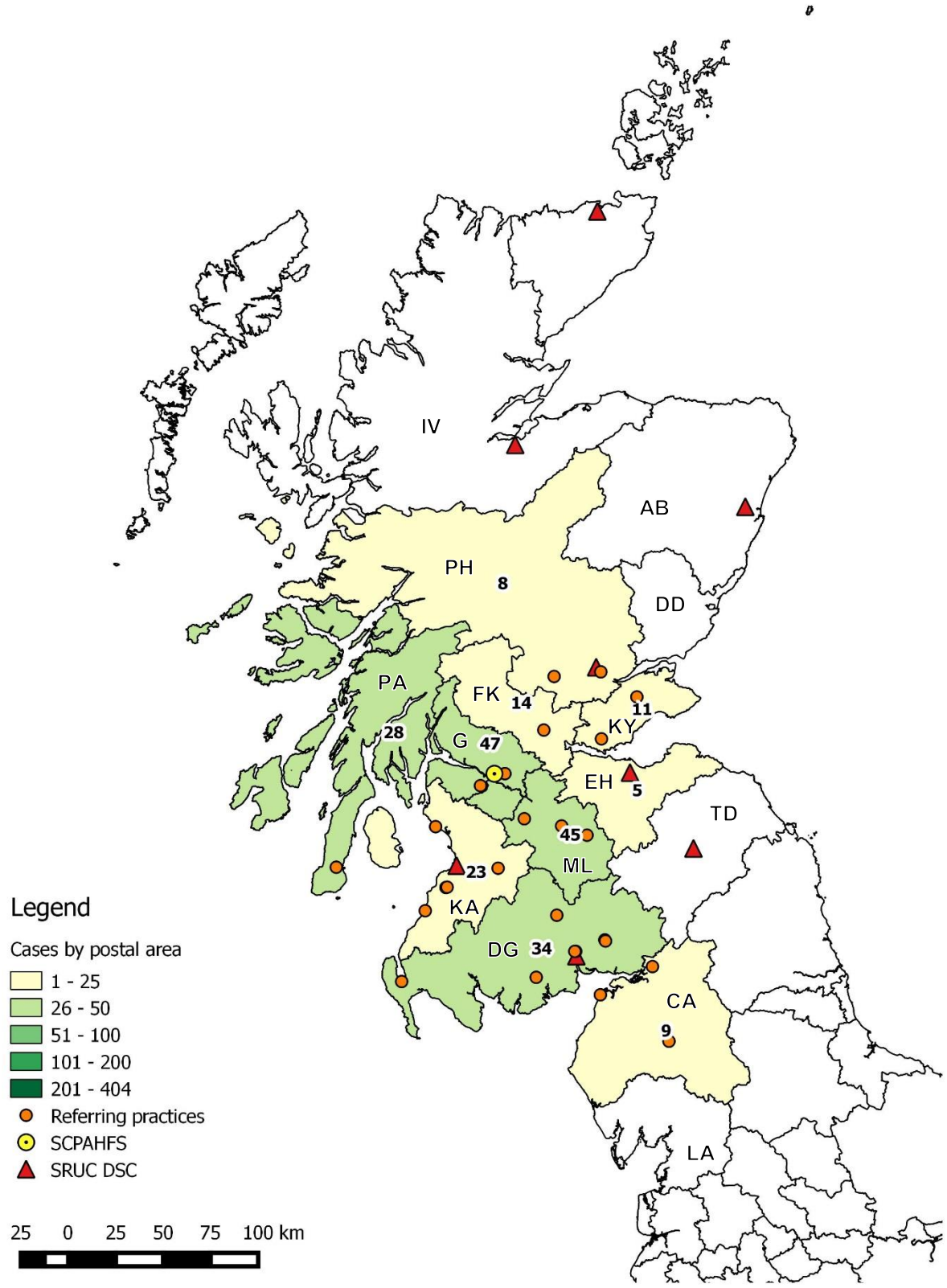


Figure 4.10 Total cases referred per postal area in 2015 and location of the respective referring veterinary practices and SRUC DSC.

4.2.3. Length of stay at the SCPAHFS

Figure 4.11 shows how long after being admitted to the SCPAHFS the animals were examined at post-mortem. The majority of the cases (58%) were euthanased within a week of their admission.

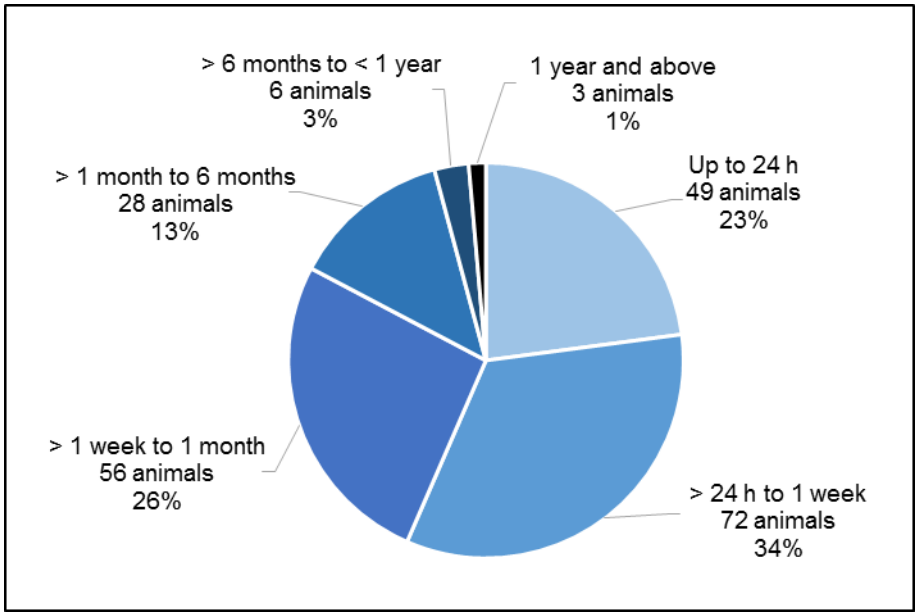


Figure 4.11 Length of stay at the SCPAHFS of the animals admitted in 2015.

4.2.4. Referral reasons

The distribution of referral reasons for cases admitted to the SCPAHFS in 2015 was very similar to the overall for the 2006-15 caseload (Figure 4.12). Figure 4.13 shows the referral reasons for cattle and sheep admitted in 2015, grouped by affected system. The main individual referral reasons (≥ 2% of the caseload) are summarised in Table 4.1.

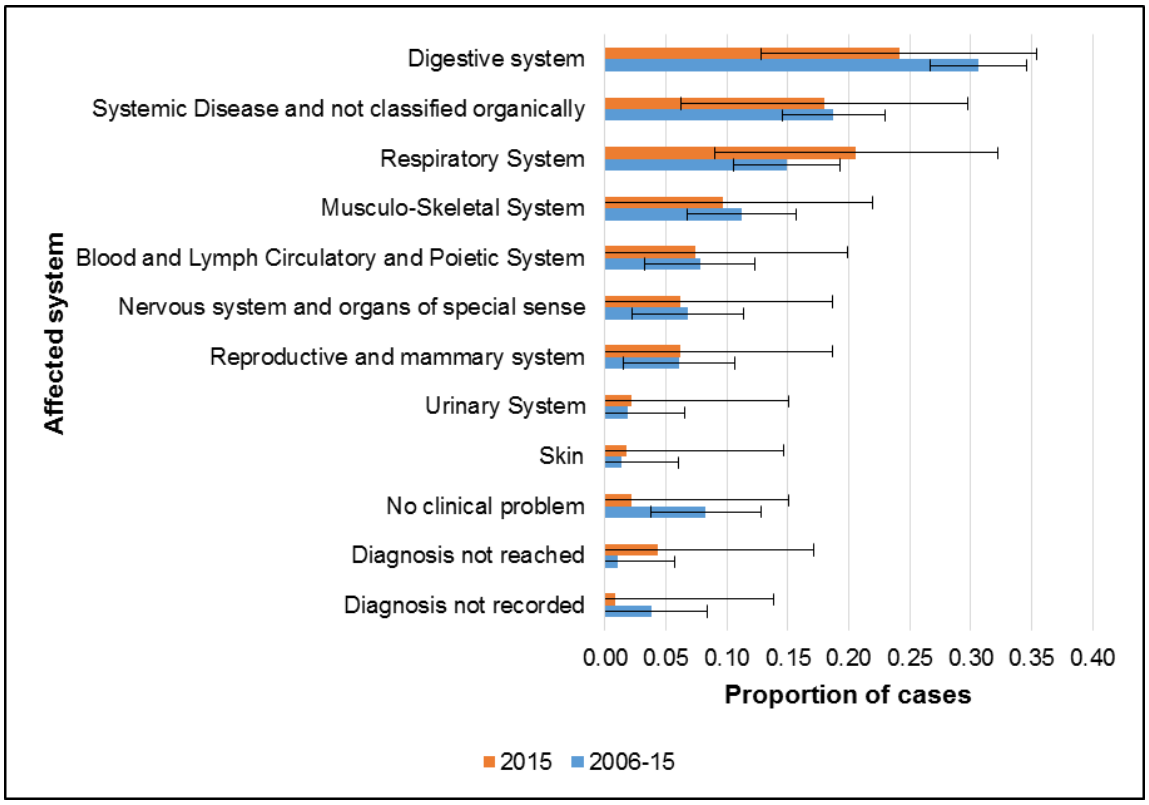


Figure 4.12 Comparison between the referral reasons grouped by affected system for the total 2006-15 caseload (blue) and the 2015 cases (orange). Error bars denote binomial 95% confidence limits.

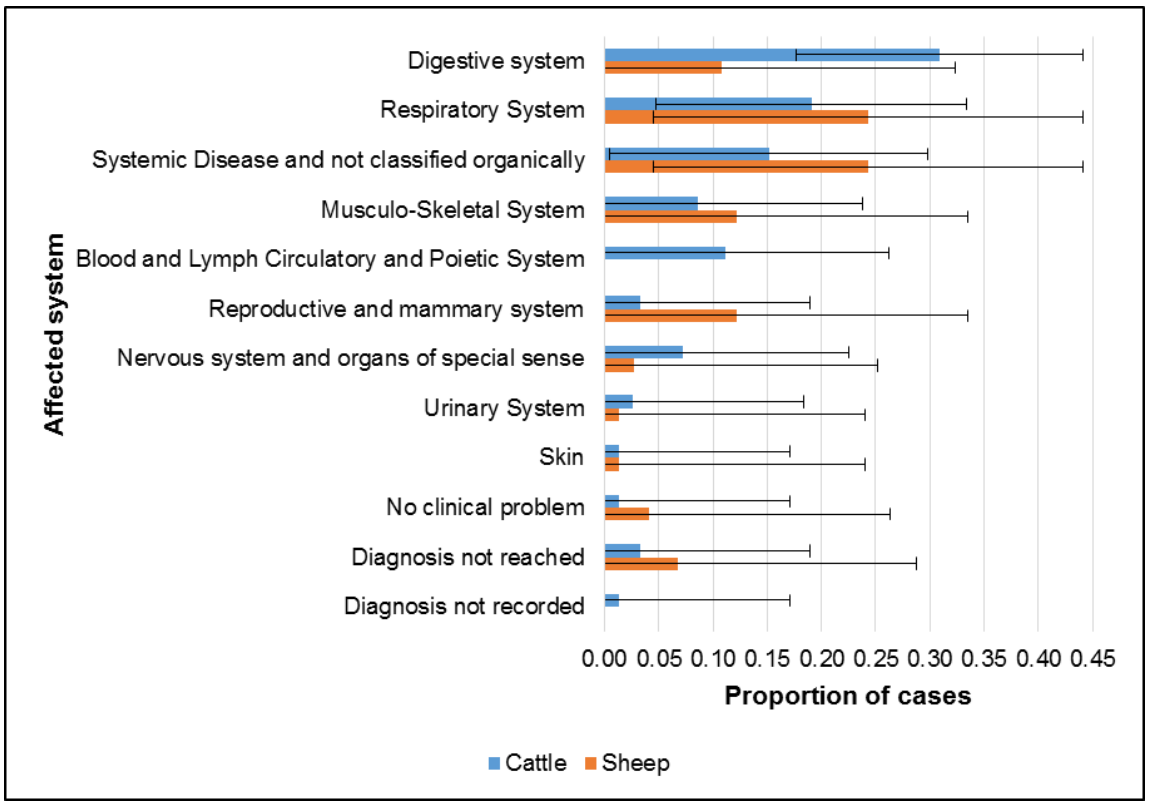


Figure 4.13 Proportion of cattle and sheep referral reasons in 2015, grouped by affected system. Error bars denote binomial 95% confidence limits.

Referral reason	Cattle	Sheep	Alpacas	Total	Total %[1]
Alterations of body weight and/or size	14	14	0	28	12
Pneumonia	23	1	0	24	11
OPA	0	18	0	18	8
Johne's disease	13	3	0	16	7
Arthritis, Polyarthritis	3	8	0	11	5
BVD PI	8	0	0	8	4
Bloating	6	0	0	6	3
Congenital abnormalities	5	1	0	6	3
Diagnosis not reached (Systemic disease)	3	3	0	6	3
Heart murmur	6	0	0	6	3
Diarrhoea	4	1	0	5	2
Healthy animal	2	3	0	5	2
Infertility	0	5	0	5	2
Pericarditis	5	0	0	5	2
Heart failure	4	0	0	4	2
Mastitis	3	1	0	4	2
Poor recovery after surgery	4	0	0	4	2
Others[2]	56	16	2	74	32
Grand Total	**159**	**74**	**2**	**235**	**103**

Table 4.1 Summary of individual referring reasons for cases admitted to the SCPAHFS in 2015. [1]Over a total of 228 cases. Some animals presented with more than one referral reason, therefore the total percentage adds up to more than 100%. [2]Those that represented less than 2% of the total 2015 caseload are grouped under 'Others'.

4.2.5. Final diagnoses

Figure 4.14 summarises the final diagnoses reached at the SCPAHFS during 2015 for cattle and sheep, compared to the 2014 VIDA diagnoses, both grouped by affected system. For 152 cattle admitted in 2015, 216 diagnoses were reached (142%), whereas 74 sheep cases presented 110 diagnoses (149%). The individual diagnoses compared to the equivalent VIDA code are presented in Figures 4.15 for cattle and 4.16 for sheep.

Focusing on the cattle caseload, 'diagnosis not reached' was the main category in the VIDA report, with 49% of the cases not having a diagnosis (14,238 samples). By contrast, at the SCPAHFS the proportion of cases that did not have a final diagnosis was substantially lower,

with only 8% of the animals without a final diagnosis (14 animals). There was also a difference between the clinical conditions diagnosed by both systems. At the SCPAHFS diseases affecting the digestive system were the main category, representing 58% of the cases (88 animals) and respiratory disease was the second most common diagnosis, reached in 29% of the cases (44 animals). By contrast, in the 2014 VIDA report, reproductive disease was the most frequent diagnosis, with 29% of the cases affected (8,524 samples) followed by digestive disease, with 23% of the cases (6,646 samples). At the SCPAHFS reproductive and mammary disease accounted for the final diagnosis of only 8% of the cases admitted in 2015.

For the 2015 SCPAHFS sheep caseload, digestive and respiratory diseases were also the main final diagnoses reached at the SCPAHFS, representing 47% (35 animals) and 43% (32 animals) of the cases, respectively. In the 2014 VIDA report, reproductive disease was again the main diagnosis in sheep (23%, 1,891 samples), followed by digestive disease (21%, 1,724 samples). However, 'diagnosis not reached' was still the first category in the VIDA sheep caseload (35%, 2,873 samples), whereas at the SCPAHFS only 9% of sheep cases did not have a final diagnosis (7 animals). At the SCPAHFS there was 1 sheep (1%) for which no information was available regarding clinical diagnosis or laboratory submissions and the post-mortem report was missing. This animal was euthanased on the same day as its admission and the case file was blank.

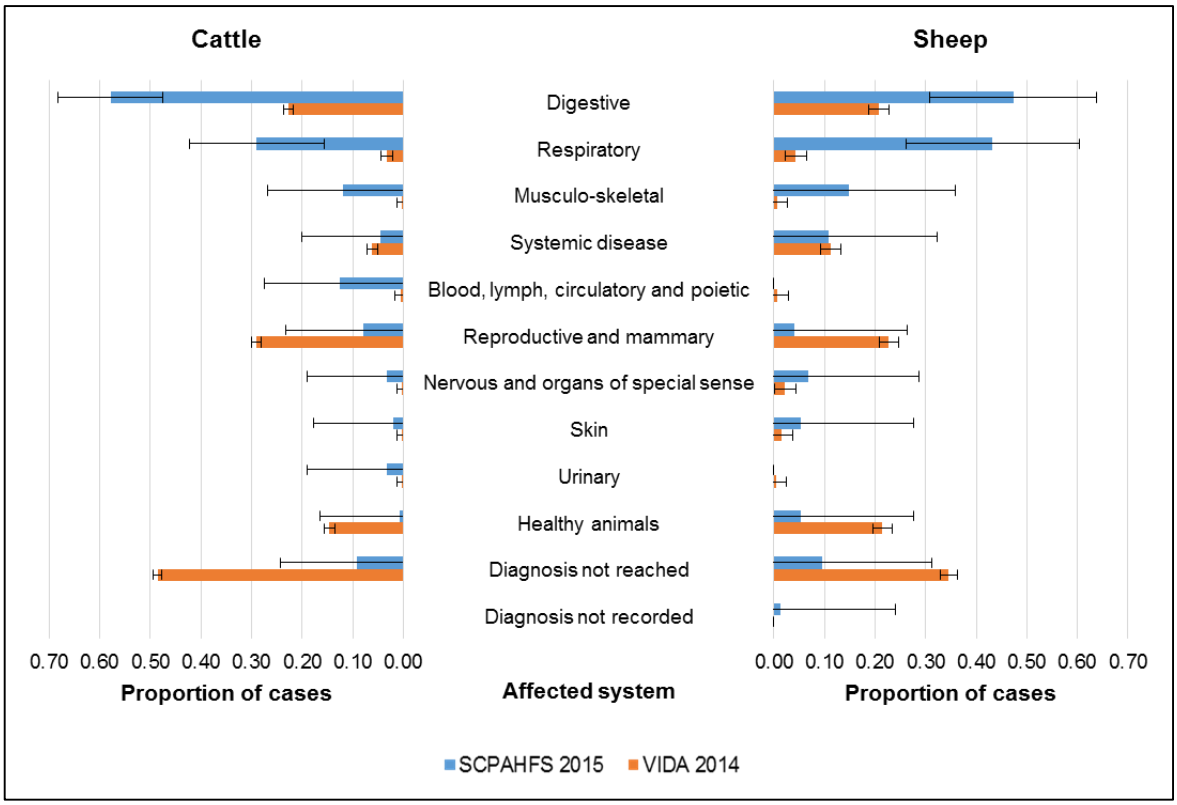


Figure 4.14 Proportion of diagnoses reached at the SCPAHFS in 2015 for cattle and sheep cases, compared to the VIDA cattle diagnoses in 2014, grouped by affected system. Error bars denote binomial 95% confidence limits.

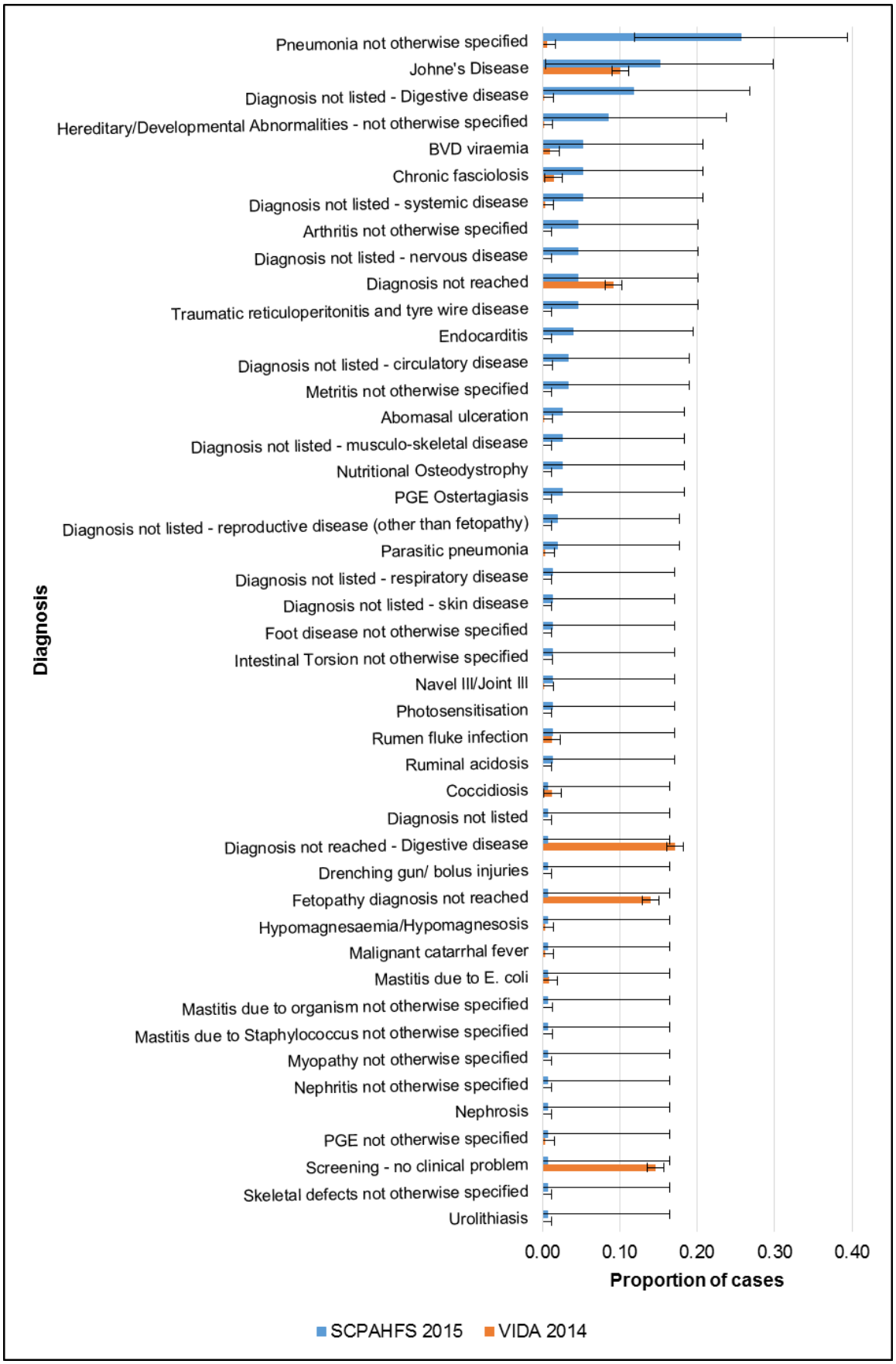


Figure 4.15 Individual final diagnoses reached at the SCPAHFS in cattle in 2015, and proportions for the same diagnoses in the 2014 VIDA cattle report. Error bars denote binomial 95% confidence limits.

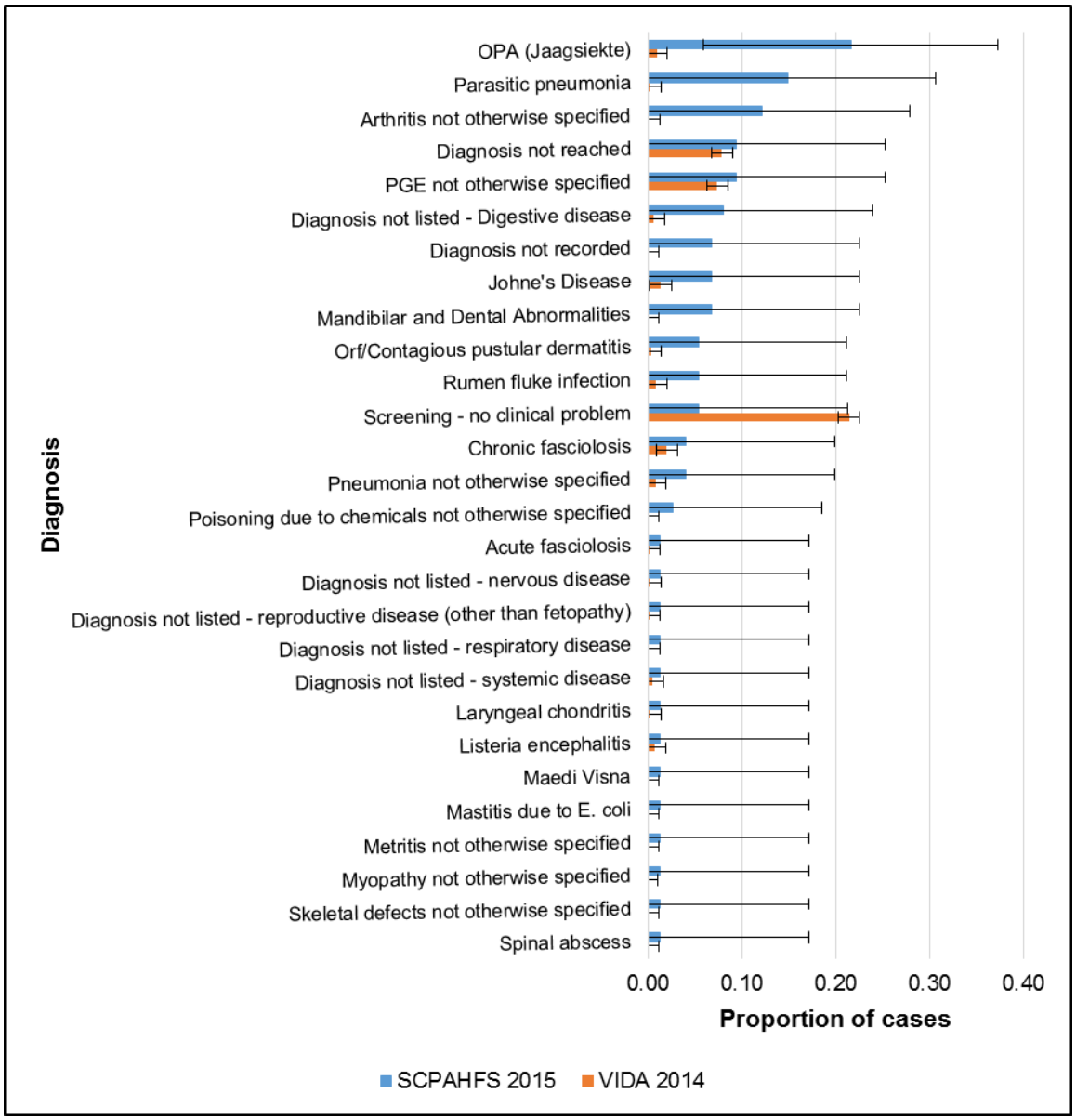


Figure 4.16 Individual final diagnoses reached at the SCPAHFS in sheep in 2015, and proportions for the same diagnoses in the 2014 VIDA sheep report. Error bars denote binomial 95% confidence limits.

4.3. Discussion

This study provided a more detailed analysis of the 2015 SCPAHFS caseload, including the final pathological diagnoses reached at the centre during that year, and compared them to the VIDA report, with the aim to evaluate the usefulness of the SCPAHFS caseload as an additional source of surveillance data.

The 2015 caseload was chosen for this study as it was the most complete dataset in the original MS Office Excel spreadsheet. In 2015, there was a small variation in the proportion of cases admitted per species at the SCPAHFS – only two alpacas were admitted and the rest of cases were cattle (67%) and sheep (32%), and the age distribution of the cases admitted in 2015 was younger than the 2006-16 overall. However, the referral reasons were representative of the 2006-15 caseload. The data had to be compared to the 2014 VIDA report as, at the time of analysing the data for this study, 2015 VIDA data had not yet been published. Additionally, it was considered appropriate to compare the data to the 2014 report since the changes in the delivery of surveillance in England and Wales the incorporation of additional PM providers and triage of samples are likely to be reflected in the 2015 VIDA results.

The diagnoses reached at the SCPAHFS during 2015 were classified following the VIDA report codes. However, with the SCPAHFS caseload it was found that many diagnoses did not have an equivalent code in the VIDA report and had to be grouped under ‘diagnosis not listed’. The codes used in this study were extracted from the report and not the original VIDA database. Some of the conditions may have had a code but were not diagnosed in VIDA samples hence did not appear in the report, although others may simply not be included in the database. This indicates that the SCPAHFS caseload may represent a population of cases that are not currently captured under a specific VIDA category. By categorising conditions, however, there can be issues with diagnoses being assigned to the wrong category if clear definitions are not provided. If data from the SCPAHFS caseload were to be used for surveillance purposes, there is a need to improve the recording methods, collating all the information under one system and using unified nomenclature and diagnoses. Of course, this would also require quality assurance and standardisation of PM diagnoses reached by

pathologists in SCPAHFS and DSC and VI centres. This would be easily achievable, and the pathologists employed at the School of Veterinary Medicine are highly qualified.

Comparisons between passive surveillance sources are always difficult since data are different by nature. Passive surveillance data are always affected by biases that vary between sources. This study found clear differences between the SCPAHFS and VIDA caseloads. Diseases of the reproductive and mammary systems were the main condition reported to DSC and VI laboratories. This is likely to be due to compulsory reporting of cattle abortions as part of the surveillance strategy for brucellosis (Department for Environment and Animal and Plant Health Agency, 2014); such cases are not referred to the SCPAHFS. Farmers and first opinion practitioners are more likely to submit samples to DSC and VI centres when animals are valuable and a diagnosis has not been reached, especially if the condition affects multiple individuals and causes high losses (Watson et al., 2008; Animal and Plant Health Agency, 2014d). By contrast, animals admitted to the SCPAHFS usually have a low value and are affected usually by chronic and endemic conditions. 'Diagnosis not reached' (DNR) cases are an important proportion of the VIDA caseload. Emphasis is put on these as they could offer insight into the emergence of new conditions (Hyder et al., 2011). However, VIDA DNR cases are often due to limited diagnostic value of the samples submitted to the laboratories (Gibbens et al., 2008; Watson et al., 2008). The SCPAHFS is set up in such a way that multiple diagnostic tests can be performed in the live animal and almost every case undergoes a post-mortem examination. Therefore, it is expected to reach a diagnosis in the majority of cases. However, the causative agents are often not identified at the SCPAHFS (e.g. bacterial agents in cases of pneumonia or arthritis). This is limited by the fact that the centre covers the costs of the PM examination but additional testing derived from PM findings has to be paid by the farmer. As these cases are often worth very little to the farmer, diagnostics beyond the gross PM are rarely performed. Additionally, the chronic nature of most cases also limits the diagnostic value of the samples, i.e. infections are no longer active.

No previous studies have been published that present the caseload and diagnoses reached at farm animal veterinary practices or teaching hospitals. However, the conditions diagnosed in sheep admitted to the SCPAHFS were similar to the diagnoses reported by a study that examined sheep at fallen stock collection centres (Lovatt and Strugnell, 2013). Apart from mastitis, which was the most frequent condition, that study reported pneumonia in 13% of

the cases, OPA in 6%, Johne's disease in 6% and neoplasia in another 6% of the examined sheep. Cases admitted to the SCPAHFS are affected by chronic and uneconomic conditions, similar to those collected by fallen stock services. The latter receive diseased animals that die or are euthanased on farm and are not submitted for PM examinations at DSC or VI centres, either because the animal was not valuable enough, because the pathology was diagnosed by the farmer or it was not perceived as a flock/herd problem. Compared to fallen stock centres, the SCPAHFS caseload presents the advantage that the infrastructure to perform tests in the live animal and PM examinations is already in place. Using data from centres like the SCPAHFS would complement the diagnoses reached at DSC and VI centres, identifying chronic or endemic conditions that may otherwise be missed and offering some insight into their changing presentation over time, especially in the event of a national control plan, such as the Scottish BVD Eradication Scheme (see Chapters 5 and 6).

In summary, results of this study have shown that the SCPAHFS caseload covers a proportion of the Scottish sheep and cattle caseload that is not currently included in the existing surveillance system. The data generated at the SCPAHFS have the potential to complement surveillance activities in Scotland, although improved and unified data recording methods are needed. The next chapter provides an example of how additional information from the cases admitted to the SCPAHFS can contribute to monitor changes in endemic conditions in Scotland. Persistent infection with BVD virus was the reason for referral of 6% of the total 2006-15 SCPAHFS caseload. The interest for bovine viral diarrhoea (BVD) is increasing in Europe, with many countries making efforts to eradicate the disease (Stahl and Alenius, 2012; The Scottish Government, 2015a). With the Scottish BVD eradication scheme entering its fourth stage in June 2015 it was decided to evaluate whether the SCPAHFS caseload could provide evidence of any changes in the presentation of BVD PI cattle that may have happened as a consequence of the launch of the Scottish BVD eradication scheme.

5. Progression of the clinical presentation of BVDV PI cattle at the SCPAHFS in relation to the launch of the Scottish BVD Eradication Scheme

5.1. Introduction

The previous two chapters have introduced the Scottish Centre for Production Animal Health and Food Safety (SCPAHFS) caseload, presented the demographics of the donated population of cases, the most common reasons for referral and the conditions diagnosed at the centre. This information has been compared to VIDA data in order to ascertain the similarities and differences between the two data sets. The data generated at the SCPAHFS often provide more information than that required to make a diagnosis and provide feedback to the farmer and referring veterinary surgeon. Some of these data have been used in various other studies and case reports. Cardiac disease cases were used in a study that evaluated the clinicopathological differences between cases of pericarditis, endocarditis and congenital heart disease (Bexiga et al., 2008). Cases have also been used to compare the differential diagnosis of bluetongue, mucosal disease and malignant catarrhal fever (MCF) (Bexiga et al., 2007). More recently, a study has analysed the characteristics of the neurological disease caseload presented at the SCPAHFS (article submitted for publication). Various reports of unusual conditions diagnosed at the SCPAHFS can also be found in the literature (Hannon et al., 2014; Gladden et al., 2015). However, to date, bovine viral diarrhoea (BVD) cases have not been reported in such a way.

In Scotland, the BVD Eradication Scheme is making progress; however, over 470 confirmed persistently infected (PI) cattle are still alive (J. Purcell, personal communication). Currently, PI animals cannot be moved to other farms but only sent to slaughter, with an exception: by applying for a special movement licence PI cattle can be admitted to the SCPAHFS to be used as teaching cases. As PI animals are worth very little to the farmer and pose a serious threat in the maintenance of BVD virus (BVDV) within a cattle population (Lindberg and Houe, 2005) the SCPAHFS is a useful option for farmers and veterinarians when trying to dispose of these animals. In one of the previous studies it was identified that between 2006

and 2015, 73 animals were admitted to the SCPAHFS for PI with BVDV or mucosal disease (MD), 6% of the total cattle caseload (Chapter 3). As BVDV is at the forefront of farmer's and veterinarians' minds, given the implementation of the eradication scheme, the aim of this study was to analyse the PI case load before and after the scheme and to evaluate any changes that may have occurred as a consequence of the implementation of the Scottish Government BVD Eradication Scheme.

5.2. Results

5.2.1. Bovine viral diarrhoea virus antigen and antibody results

Table 5.1 summarises the cases that were investigated as part of this study as discussed in the Material and Methods section (Chapter 2). A total of 91 cases were identified as being potential cases for this study. Five cases had missing case files (5%), two cases had not been tested for antigen (2%) and 11 were antigen negative (12%), therefore 73 cases remained as having positive antigen results (80%). Further analysis of these 73 cases found that 17 were only tested once at SCPAHFS for BVDV antigen (23%), three animals were tested twice but less than 21 days apart (4%) and one animal was tested twice but the second antigen result was negative (1%). These were also excluded from the study. Finally, there was a case that originated from England and this was also dismissed since the farm was not affected by the Scottish BVD Eradication Scheme. A total of 51 animals were defined as BVDV PI and included in this study. These represent 1% of the total PI cattle identified between the start of the scheme and August 2016 (J. Purcell, personal communication). Of the animals that were tested for BVDV antigen at the SCPAHFS, three tested positive for antibody (BVDV antibody p80 ELISA).

Referral reason or post-mortem diagnosis	Ag +ve	Ag -ve	Not tested	Missing	Total
BVD or BVD PI	53	10	1	4	**68**
Mucosal disease	11	0	0	0	**11**
Cerebellar hypoplasia	0	1	1	1	**3**
Others	9	N/A	N/A	N/A	**9**
Total	**73**	**11**	**2**	**5**	**91**

Table 5.1 Summary of case files searched for BVDV antigen positive results and those that had negative or missing results or that were not tested. Highlighted in yellow are the cases that were selected for the study. Later, 22 out of 73 were also excluded from the analysis.

5.2.2. Case signalment

Of the total 51 BVD PI cases, 25 were admitted before the start of the BVD Eradication Scheme (January 2006 – August 2010) and 26 after (September 2010 – December 2015). Figure 5.1 shows the number of cases admitted per year. The year with most cases was 2009, with 11 BVD PIs admitted that year. The only year without cases was 2011 and two PIs were admitted in 2010, one in May and one in August, and therefore both were classified as 'pre-scheme' cases.

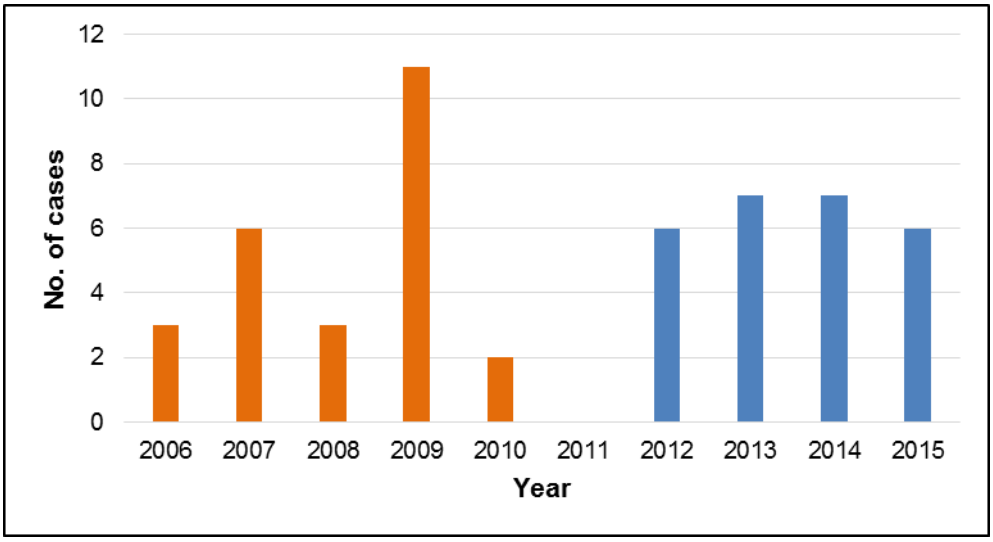


Figure 5.1 Number of BVD PIs admitted per year in relation to the start of the Eradication Scheme (orange before, blue after). Two animals were admitted in 2010, one in May and one in August, and therefore both fall under the 'pre-scheme' category.

Figure 5.2 shows the signalment (beef or dairy, sex and age group) of the BVD PIs admitted before and after the start of the Eradication Scheme. The majority of BVD PIs originated from beef farms, both before and after the scheme, although there was an apparent increase in dairy cases after 2010 (no significant difference, Chi-square test, p = 0.242). No differences (Chi-square test, p = 0.925) were observed in the proportion of female and male cases admitted before or after the scheme, with female cases being nearly 70% of the admissions. Regarding the ages of the BVD PIs, although the difference was not significant (Chi-square test, p = 0.057), BVD PIs presented at the SCPAHFS tended to be younger (under one year old) after the start of the Scheme. The median age of animals admitted before the start of the scheme was 12 months old (range from four months old to four years and three months old), whereas the median age of animals admitted after the scheme started was 6 months old (range from one month old to two years and 11 months old).

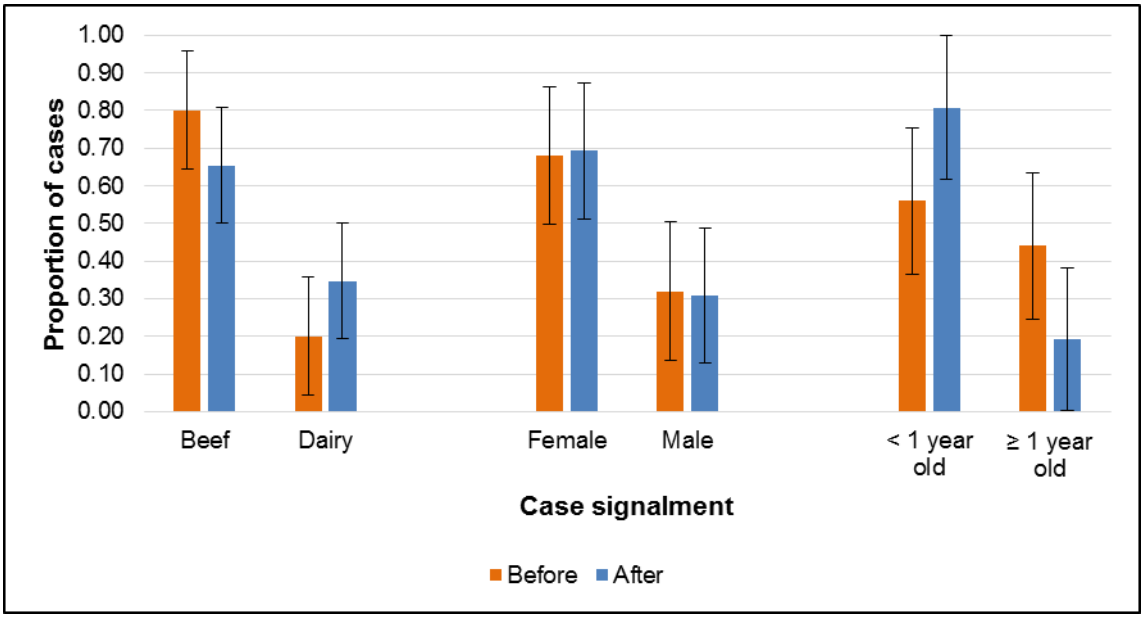


Figure 5.2 Case signalment before and after the start of the eradication scheme. Number of beef, dairy, female, male and age distribution of the BVD PI cattle included in the study. Error bars denote binomial 95% confidence limits.

5.2.3. Origin of the cases

Figure 5.4 shows the total cases referred per postal area and the location of the referring veterinary practices. Figures 5.4 and 5.5 show the distribution of cases and practices before and after the start of the scheme, respectively. No postcodes were missing for the cases' farms of origin and only one referring practice could not be located. Cases originated from Central and South-West Scotland and, as with the 2006-15 SCPAHFS caseload (section 3.2.2), postal areas adjacent to Glasgow referred the most cases. A total of 16 different veterinary practices referred BVD PI cases between 2006 and 2015 and the animals originated from 32 farms. Of the practices, six referred cases only before the Scheme, seven only after the Scheme had started and three referred cases during both stages. There were no farms that sent cases both before and after the Scheme started – 15 farms referred cases before and 17 after.

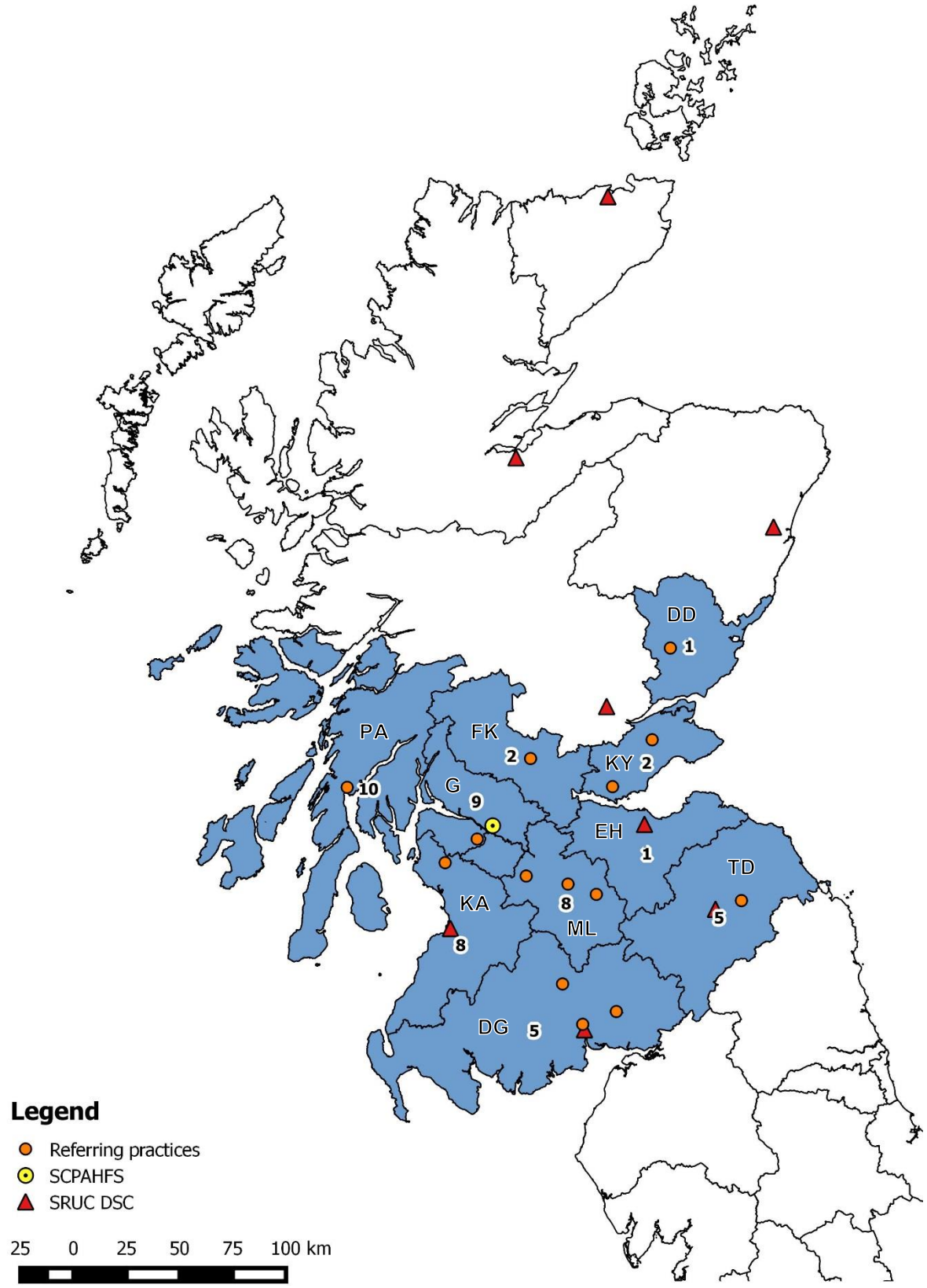


Figure 5.3 Total number of BVD PI cases referred per postal area and location of their referring veterinary practices.

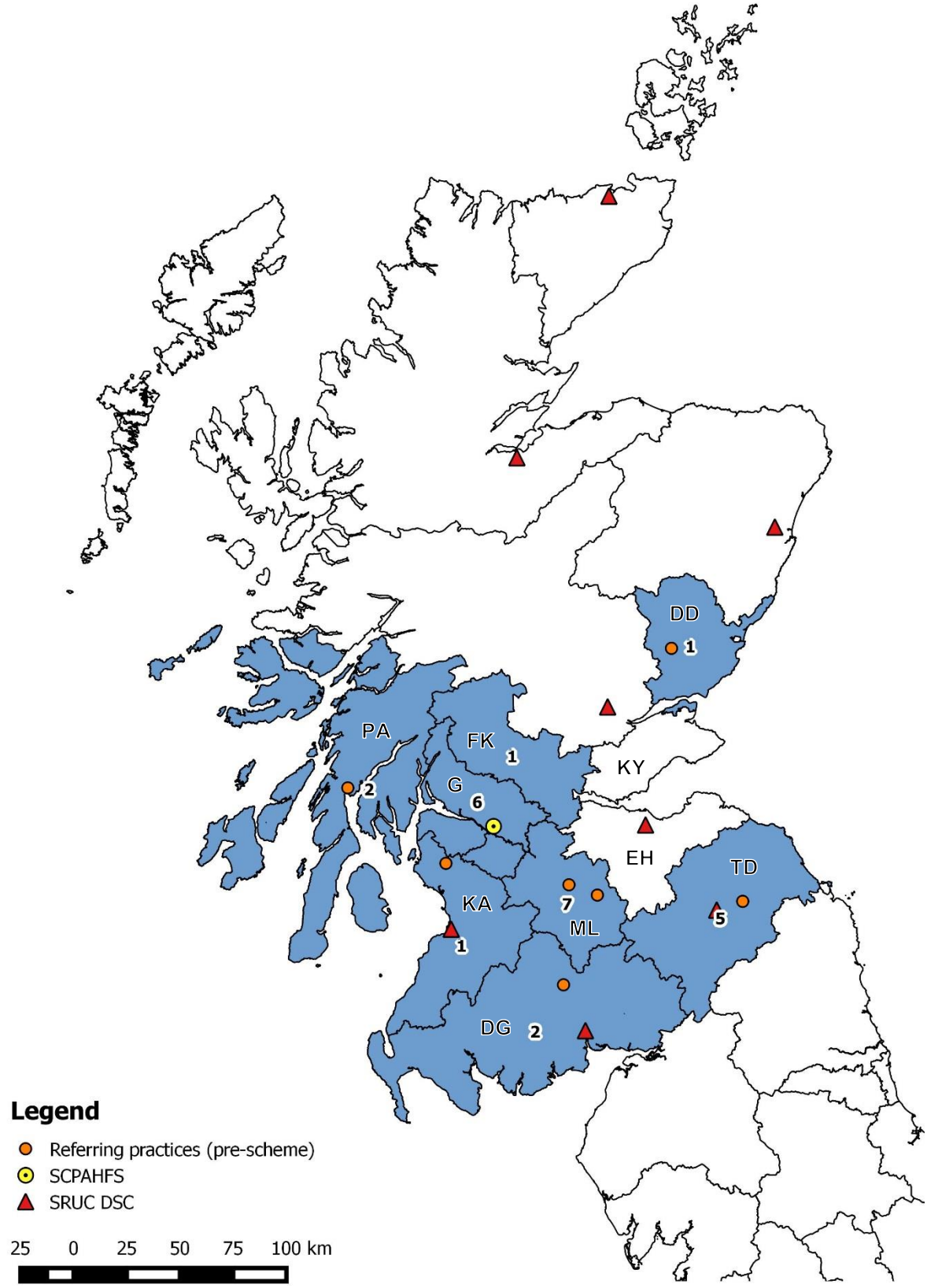


Figure 5.4 Number of BVD PI cases referred per postal area before the start of the Eradication Scheme and location of their referring veterinary practices.

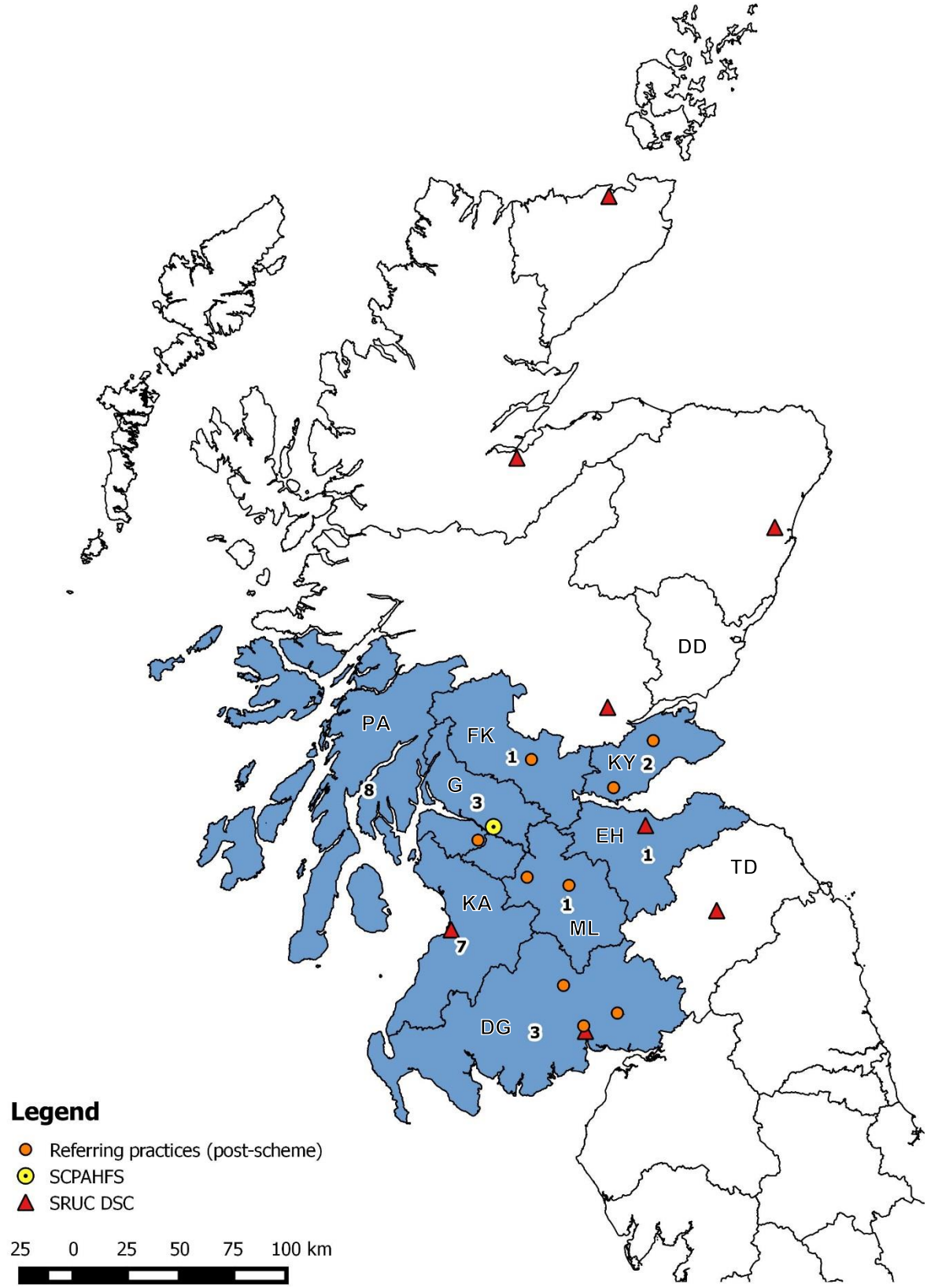


Figure 5.5 Number of BVD PI cases referred per postal area after the start of the Eradication Scheme and location of their referring veterinary practices.

5.2.4. History

In the history taken from the farmer, before the start of the scheme, ten farmers did not mention BVD and one history was blank (Figure 5.6). During the scheme only two farmers did not mention BVD (Figure 5.7). Looking at the veterinarian history, two referring veterinarians did not mention BVD before the scheme (one blank history) (Figure 5.8). One of them was referred as a suspected case of Johne's disease and the second one as a case of pericarditis. After the scheme, the referring veterinarian did not mention BVD in two cases (Figure 5.9) that were twin calves referred for coccidiosis. In this case, the farmer mentioned BVD, but in relation to previous diseases on farm: he was not expecting these animals to be PI, and both were tested twice at the SCPAHFS.

Figures 5.10 to 5.13 show the number of cases that the farmer or referring veterinary practitioner mentioned clinical signs before and after the scheme. The proportions of farmers that mentioned signs were similar both before and after the start of the scheme. No significant differences were found in the number of veterinarians that reported clinical signs (Chi-square test, $p = 0.266$), although an apparently smaller proportion of animals were referred with signs after the start of the scheme. The individual signs mentioned by the farmer and veterinarian are summarised in Figures 5.14 and 5.15 (diagnoses of Johne's disease, pericarditis and coccidiosis not included).

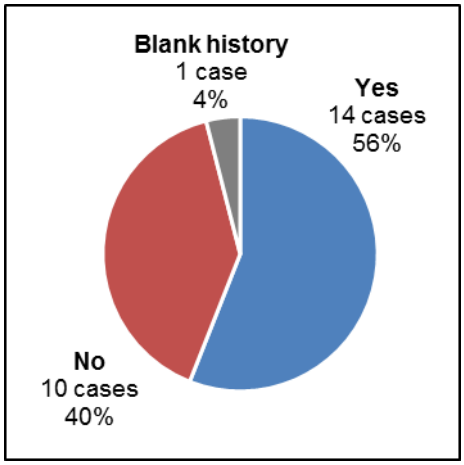


Figure 5.6 Number of cases in which the farmer mentioned BVD or not in the history before the start of the Eradication Scheme.

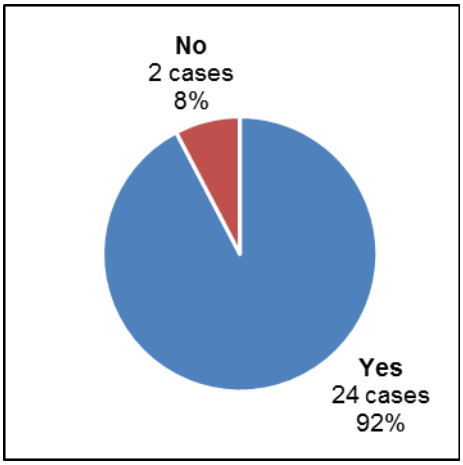


Figure 5.7 Number of cases in which the farmer mentioned BVD or not in the history after the Eradication Scheme started.

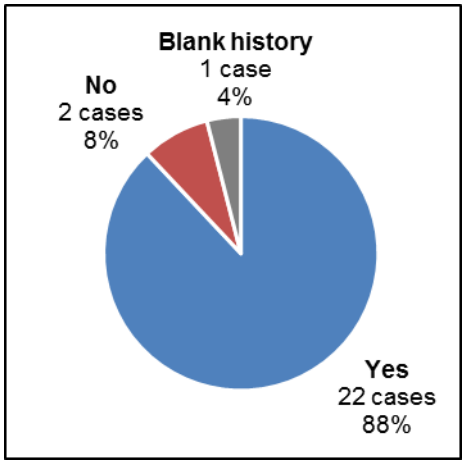


Figure 5.8 Number of cases that the referring veterinarian mentioned BVD in the history before the start of the Eradication Scheme.

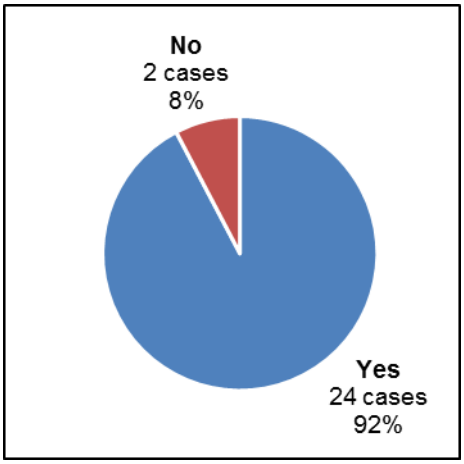


Figure 5.9 Number of cases that the referring veterinarian mentioned BVD in the history after the start of the Eradication Scheme.

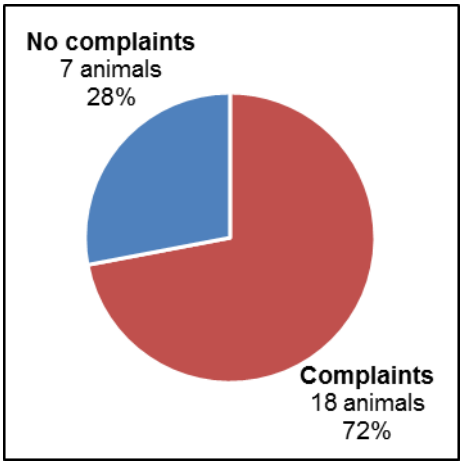


Figure 5.10 Number of cases that the farmer reported clinical signs in the history before the start of the Scheme.

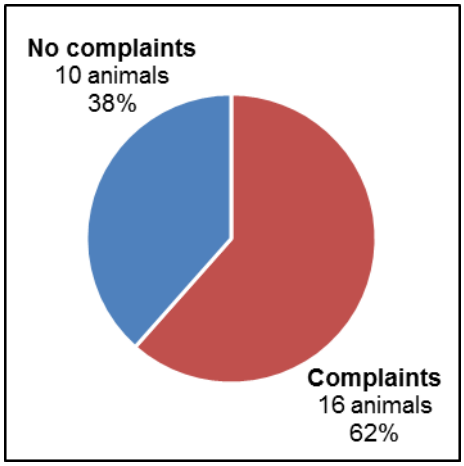


Figure 5.11 Number of cases that the farmer reported clinical signs in the history after the start of the Scheme.

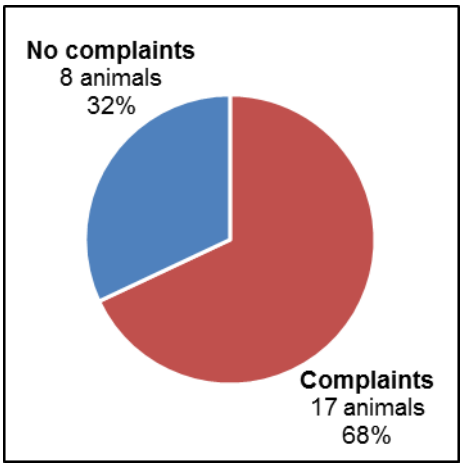


Figure 5.12 Number of cases that the veterinarian reported in the history before the start of the Scheme.

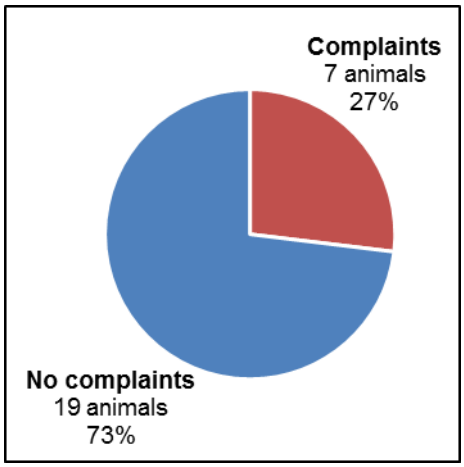


Figure 5.13 Number of cases that the veterinarian reported clinical signs in the history after the start of the Scheme.

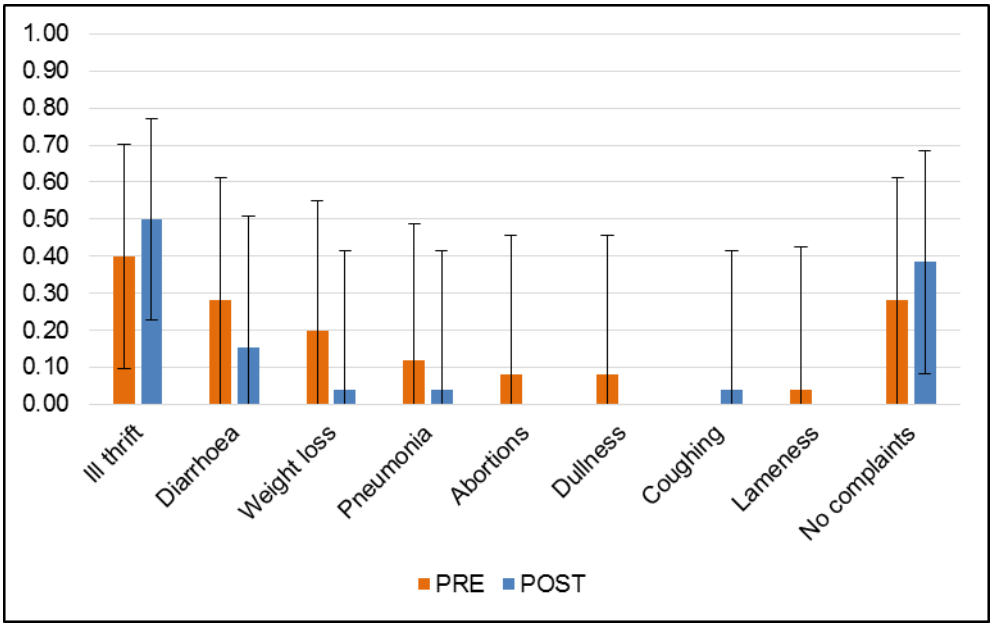


Figure 5.14 Other clinical signs reported by the farmer before and after the start of the Eradication Scheme. Error bars denote binomial 95% confidence limits.

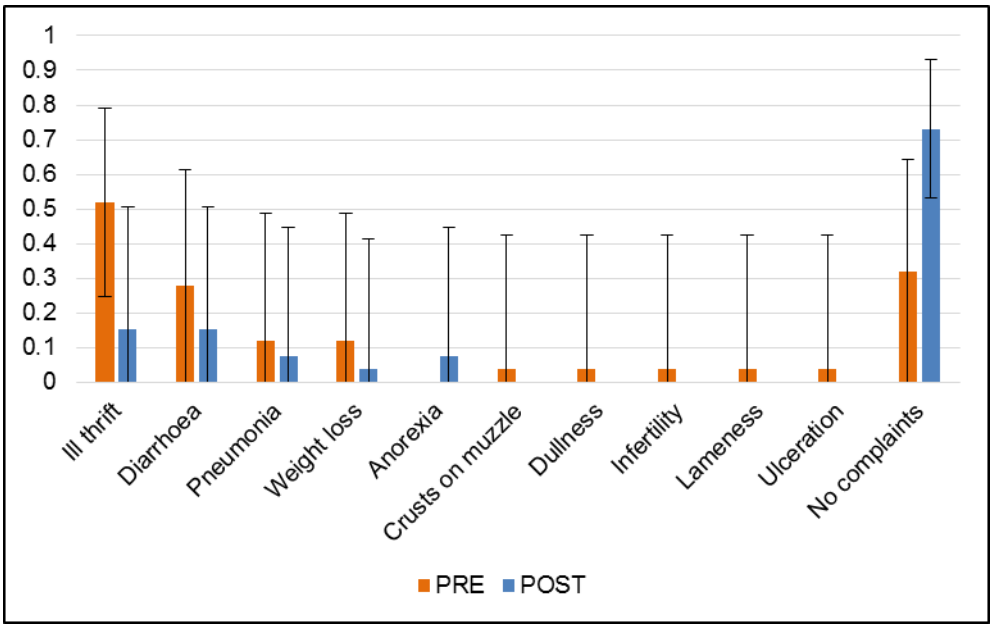


Figure 5.15 Other clinical signs reported by the referring veterinary practitioner before and after the start of the Eradication Scheme. Error bars denote binomial 95% confidence limits.

5.2.5. Clinical presentation

Figure 5.16 and Figure 5.17 show the number of cases that were presented with clinical signs or had no clinical signs on the first full clinical examination at the SCPAHFS. The majority of BVD PIs admitted before the start of the scheme presented with clinical signs, while after the scheme the majority had no detectable clinical signs (Chi-square test, p = 0.036). The clinical signs diagnosed at the SCPAHFS are presented in Figure 5.18. Respiratory disease was the main clinical finding and there were eight cases of mucosal disease diagnosed before the start of the scheme, but none after.

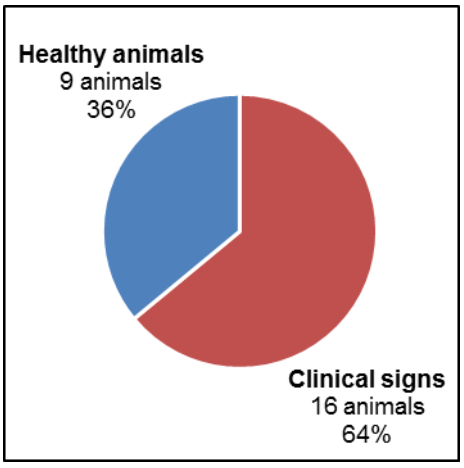


Figure 5.16 Number of cases presented with clinical signs on the first clinical examination before the start of the scheme.

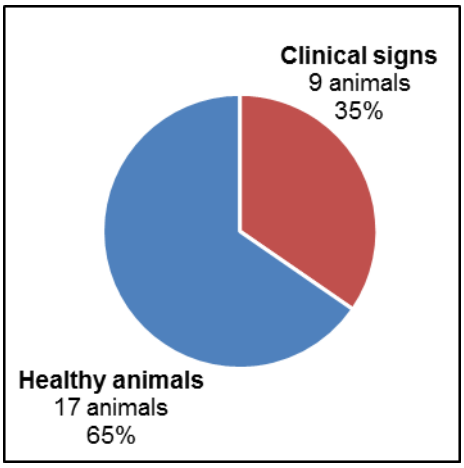


Figure 5.17 Number of cases presented with clinical signs on the first clinical examination after the start of the scheme.

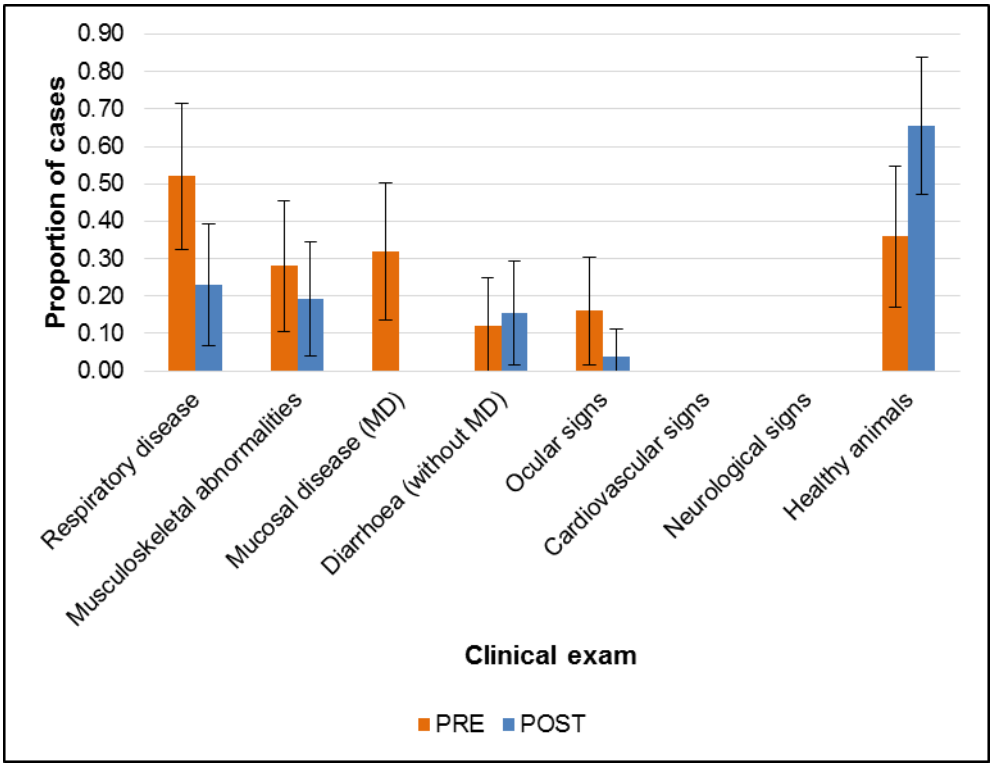


Figure 5.18 Proportion of main clinical signs detected on the first clinical examination of BVD PIs admitted before (Pre) and after (Post) the start of the Eradication Scheme. Error bars denote binomial 95% confidence limits.

5.2.6. Post-mortem diagnoses

Figure 5.19 summarises the number of cases that had abnormal findings on the post-mortem (PM) examination, those that had no significant findings and those that were missing a post-mortem report, before and after the start of the BVD eradication scheme. Surprisingly, more animals presented gross PM findings after the start of the scheme than before. Figure 5.20 presents all the individual PM diagnoses reached in the BVD PI cases. Bronchopneumonia was the main finding in both stages, present in 32% of the BVD PI animals admitted before the scheme started and 69% after. Mucosal disease was only diagnosed in cases admitted before the scheme started (eight animals, 32%). There was one case admitted before (4%) and five after (19%) that presented a minor degree of gastrointestinal ulceration on the PM examination, without associated MD. There were more cases with no significant gross post-mortem findings

before (8 animals, 32%) than after (4 animals, 15%) but also more animals were missing a post-mortem report before (3 animals, 12%) than after (1 animal, 4%).

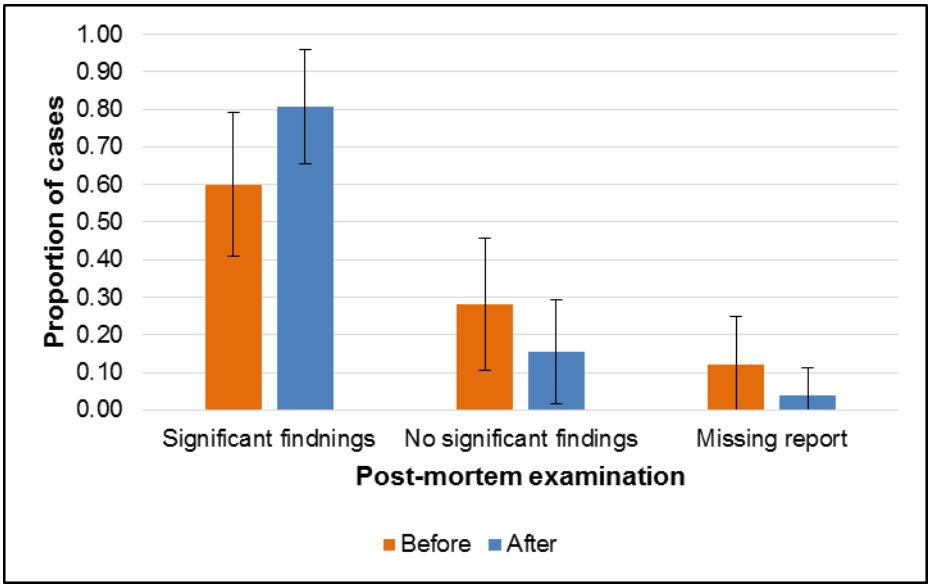


Figure 5.19 Findings on the post-mortem examination of cases admitted before and after the start of the eradication scheme. Error bars denote binomial 95% confidence limits.

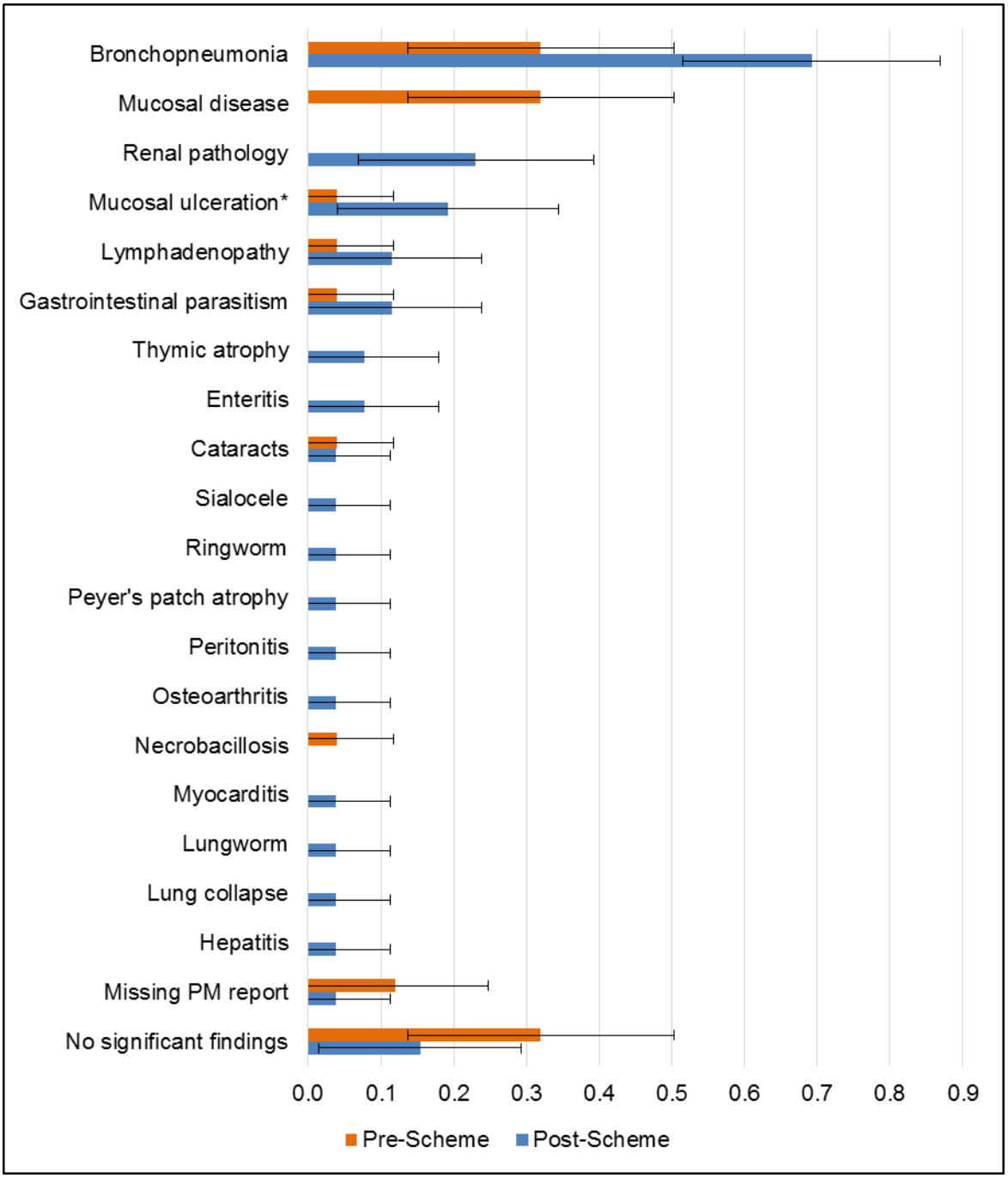


Figure 5.20 Proportion of post-mortem findings reached before (pre) and after (post) the start of the Eradication Scheme (*No Associated Disease). Error bars denote binomial 95% confidence limits.

5.3. Discussion

This study was designed to evaluate any changes in the clinical presentation of BVDV PI cattle that may have occurred as a consequence of the launch of the Scottish BVD eradication scheme. Since the scheme started, the prevalence of Scottish herds classed as not-negative for BVDV has decreased from 40% in 2010 to 12% in 2015 (Carty and Caldow, 2016) and by August 2016 over 4,700 PI animals had been identified in total, 472 of which were still alive (J. Purcell, personal communication, August 2016). The year with most BVDV PI animals admitted to the SCPAHFS was 2009, before the start of the scheme, with 11 cases. This increase was due to one of the farms that the SCPAHFS works with controlling the disease during that year. Six PI calves were identified and referred to the SCPAHFS. The farm has since then been BVD negative. In 2010, the two PIs admitted that year were referred before the start of the Scheme in September and none were admitted during 2011. However, since 2012, the year the scheme became compulsory, the number of cases admitted has been constant (six or seven animals per year), which is consistent with farmers identifying and removing animals. After the application of the latest control measures and the removal of the bulk tank milk (BTM) test options in 2014, the number of PIs identified per year has increased from 742 in 2014, to 1,479 in 2015 (J. Purcell, personal communication). This increase in the number of PIs identified did not result in more cases being admitted at the SCPAHFS in 2015. However, given the existing movement restrictions on BVD PI and untested cattle and the fact that first opinion veterinary practitioners and farmers may not be aware of the possibility of sending PI cattle to the SCPAHFS, may have affected the number of cases being referred to the centre.

Cattle PI with BVDV admitted to the SCPAHFS originated from South-West of Scotland, one of the regions with the highest percentage of not-negative herds (The Scottish Government, 2016d). The fact that farmers referred cases to the SCPAHFS either before or after the start of the scheme but not in both periods is likely to be consistent with regional progress made with the control scheme. For example, the Ayrshire (KA postal area) and Lanarkshire (ML) have gone from over 35% and 28-35% of not-negative herds in 2013 to 22-27% and 7-9% in 2015, respectively (The Scottish Government, 2016d).

The majority of PI cattle in this study originated from beef herds, which agrees with the observation that the disease is being controlled faster in beef than dairy farms. In 2011, after the first stage of the Scottish eradication scheme, it was calculated that 52% of Scottish dairy herds were exposed to the virus, as opposed to 23% of beef herds and, by September 2015, the proportions had decreased to 31 and 9% respectively (Carty and Caldow, 2016). This represents a reduction of 40% of exposed dairy herds and 61% of beef. Evidence has shown that farmers take longer to initiate further investigations when a positive antibody result is obtained from a milk sample rather than blood (Duncan et al., 2016). In addition, dairy farmers seem to rely more on vaccines to control BVD than beef farmers (Cowley et al., 2012), which may interfere with BVD investigations. Therefore, beef farmers are likely to be faster in identifying and removing PI cattle, sending more cases to the SCPAHFS.

Animals admitted to the SCPAHFS after the start of the eradication scheme tended to be younger than those admitted before. Although the difference was not statistically significant, this is likely to be due to the low number of cases in the study. This finding indicates that, as a consequence of compulsory testing, BVDV PI cattle are being identified and removed faster, resulting in less chances to transmit the virus. At the same time, younger BVD PIs will have had less chances to suffer immunosuppressive effects of the infection, presenting less clinical disease as shown by the reduction in the number of animals that presented with clinical disease after the start of the scheme. This is supported by the fact that first opinion veterinary practitioners reported fewer clinical signs in the history of animals referred after the start of the scheme and this group of cases presented less clinical disease on admission at the SCPAHFS. By contrast, there were no differences in the percentage of farmers that mentioned clinical signs in the history of cases admitted before or after the scheme. Farmers may be inclined to report clinical signs if they feel that they need to report disease for the animals to be accepted for admission to the SCPAHFS, when this is not the case. Ill thrift was the most common clinical sign reported in the animals' history both before and after the scheme started. This is consistent with the evidence that PI animals can present slow growth rates and be more susceptible to secondary diseases, resulting in poorer performance than uninfected cattle (Taylor et al., 1997; Stokstad and Løken, 2002). In this study, the body condition and growth rates of the animals were not evaluated given the different breeds and ages of the animals and the fact that body condition scores (BCS) and

weights were not consistently recorded on the cases' clinical examination forms. However, a considerable proportion of BVD PIs were clinically normal. Of those that presented clinical signs respiratory disease was the most common diagnosis, being more frequent in cases admitted before the scheme started (52% before and 23% after). In contrast, bronchopneumonia was reported on PM examination of more cases admitted after the scheme (32% before, 69% after). This result, however, may be affected by a lack of consistency in the format of PM reports during the years included in this study. In addition to the fact that more PM reports were missing in cases admitted before the scheme started, it was found that prior to 2009 the results of PM examinations were often handwritten on the animal's case file by the SCPAHFS clinician or the pathologist on duty and they only included the main PM finding. This is also reflected in the number of individual PM diagnoses identified in both periods (Figure 5.26). There was a wider variety of pathologies recorded after the start of the scheme (7 before, 18 after). Secondary conditions like bronchopneumonia were likely to be underreported in cases admitted before the scheme started in 2010. Secondary pathologies may have been present, however, these may have been deemed not relevant and were not consistently recorded in the PM reports of animals admitted before 2009.

Respiratory pathology was present in 23% to 69% of the BVD PIs admitted during the whole length of the study. This finding is consistent with studies that have highlighted the increased predisposition towards respiratory disease in animals infected with BVDV (Bolin, 2002). A study that followed the clinical progression of 28 BVD PI calves found that 25% of them presented gross pneumonic lesions at PM as the only significant pathology (Taylor et al., 1997). In a more recent study that analysed the clinical presentation of BVD PI cattle admitted to a clinic for ruminants of the University of Zurich, respiratory disease was present in 63% of the animals (Bachofen et al., 2010). The same study reported that the most common clinical signs mentioned by the farmer in the cases' history were diarrhoea (41%), pneumonia (20%) or both (9%) and neurological signs (10%). At the SCPAHFS, diarrhoea was more frequently reported as a clinical sign than pneumonia and, although congenital neurological malformations have been reported in cattle PI with BVDV (Otter et al., 2009), none of the PIs in this study were reported to have neurological disease in the history or were diagnosed with neurological disease at the time of clinical examination. Two of the PIs admitted to the SCPAHFS presented with

cataracts, an abnormality that has been associated with congenital BVDV infection (Agerholm et al., 2015).

The results of this study may be interpreted to suggest that the eradication scheme has resulted in an obvious improvement in awareness about BVD amongst farmers, as shown by the increase in the number of farmers that mentioned BVD in the history of cases admitted after the scheme started (56% before, 92% after). However, following the implementation of the first control measures whereby movements were restricted, SCPAHFS clinicians were required to ask about the farm´s BVD status which may have been a factor in the apparent increased awareness amongst farmers. Referring veterinary practitioners mentioned the disease in most cases both before and after the scheme, which indicates that the veterinary profession had a good awareness of the disease. However, before the scheme started three cases that were diagnosed with MD at the SCPAHFS were initially referred as Johne's disease (paratuberculosis) and coccidiosis cases. As eradication programmes make progress and severe disease associated with BVD decreases, veterinary practitioners will need to remain aware of the clinical presentation of MD, which could resemble other important ulcerative conditions (e.g. malignant catarrhal fever, foot-and-mouth disease) some of which are notifiable (Taylor et al., 1994; Holliman, 2005; Bexiga et al., 2007).

Diagnosis of PI with BVDV in this study was based on evidence of two positive antigen results in samples taken at least 21 days apart and/or a confirmed diagnosis of MD at post-mortem. All the animals diagnosed with MD tested positive for antigen at the SCPAHFS, but none were re-tested at the centre and only four out of eight had been tested on farm. It may have been the case that animals at the SCPAHFS were euthanased before a second sample could be collected. The lesions presented at post-mortem were consistent with MD, but it is still a possibility that these animals were not PI but transiently infected (TI) animals affected by severe acute presentations of the disease (Liebler-Tenorio et al., 2003). A final MD diagnosis would have required isolation of the cytopathic (cp) BVDV strain from the affected animals. Bachofen et al. (2010) isolated cp-BVDV from MD cases and associated the results with a 'mucosal index', calculated based on the number of organs that presented mucosal ulceration at PM, and established a threshold to identify MD using the index. This calculation was not possible in this study given that some

PM reports only included a final diagnosis. As this study was based on retrospective data, this could not be performed; however, this highlights the importance of case definitions and following diagnostic protocols if data are to be used for research or surveillance purposes.

To summarise, the results of this study indicate that BVD PIs in Scotland are being identified and removed from farms at earlier stages of disease, reducing the risk of transmission of the virus. Younger PI cattle have less chances to succumb to secondary disease and be exposed to cp-BVDV strains and therefore present with less clinical disease. As eradication schemes progress and the population of cattle susceptible to BVDV expands, the potential costs of missing BVDV cases increases and veterinary practitioners cannot rely on the clinical presentation of the disease to detect incursions anymore. This is highlighted in the following and last study of this thesis, which presents the case of a farm BVD outbreak that was detected due to the compulsory testing of the eradication scheme.

6. Bovine Viral Diarrhoea Farm Case Study

6.1. Introduction

The aim of any national eradication scheme is to reduce the impact that a disease has on a region's farming industry, in terms of animal health, welfare and its economy. Case studies are a useful method to analyse the effect that certain measures have at the farm level, as well as to understand the farmer's perceptions about the eradication scheme. During the collection of data for the bovine viral diarrhoea (BVD) study, five cases referred from the same farm in a period of just over a year were identified. In the history of the first case, it was mentioned that the animal was the first BVD virus (BVDV) persistently infected (PI) calf found in the herd. Additionally, the tests that enabled detection of the outbreak were performed due to the compulsory, second stage of the Scottish BVD Eradication Scheme. A meeting was arranged with the farmer and his/her first opinion veterinarian, with the aim to reconstruct the events, analyse the costs and outcomes of the outbreak and present the farmer's perceptions.

6.2. Farm history

Located in south west Scotland, the farm is divided into two units: 156 acres located at the home farm and 540 acres in a new farm acquired in 2010. The owners traditionally kept a flock of 600 Scottish Blackface breeding ewes at the home farm. In October 2010, the new farm was acquired through a leasing contract and a cattle herd was started with 27 cows. By 2012 the herd size had increased to 50-60 cattle and in 2015 the numbers reached 111 cows. No stock were kept at the new farm prior to the farmer renting it and the initial herd was mainly Aberdeen Angus cross cows and pregnant heifers sourced from different markets in Scotland. Two bulls, a two-year old Aberdeen Angus and a two-year, two-month old Simmental were also acquired at the time from a BVDV accredited breeder. The last stock were bought in in 2013 and since 2014 the farm has been relying on homebred heifers for replacements. The long term plan is to only buy

in bulls and have 100 breeding cows and 25 to 30 bulling heifers coming into the herd each year. Currently, replacement heifers and ewe lambs are reared at the home farm and then moved to the new farm in time for mating. In the long term, the aim is to rear and breed the heifer replacements at the home farm and then send them to the new farm as in calf heifers.

There are two farms neighbouring the home farm and two farms neighbouring the new farm. At the home farm, animals have nose-to-nose contact across the boundary fences with both neighbours. Contact with a third potential neighbour is separated by a road. At the new farm, electric fences were put in place in addition to the boundary fences to prevent contact with neighbouring stock. Confirmation of the BVD status of all the neighbours is unknown, although it is thought that all the herds in contact with the new farm are currently BVD negative based on mandatory tests as per the Scottish BVD eradication scheme.

All lambing and calving takes place at the new farm. Calving currently extends from January until the middle of April. Lambing takes place in March. Cows are typically out-wintered but housed four to six weeks prior to calving. Once the dam has calved and the calf has established a bond with its mother they are turned out to grass, assuming that the weather is favourable. Calves are given access to creep feed 12 weeks prior to sale in the store market.

By December 2015 the farmer owned three bulls. A fourth bull was sold recently, after his fifth breeding season and there are plans to buy a new replacement soon. The farmer has been using the same accredited breeder since he bought the first two bulls.

6.3. The outbreak

The BVD outbreak on this farm is summarised in a timeline in Figure 6.1 in relation to the progression of the Scottish BVD eradication scheme. The first BVD test performed on this farm was in March 2012 to fulfil the requirements of the second stage of the Scottish BVD Eradication Scheme. No tests were performed during the initial stage of the scheme (September 2010 – April 2011), when screening was voluntary but subsidised. The chosen testing method

was the calf check test. A group of 13 heifers between 9 and 18 months old were tested for antibody (blood antigen capture enzyme-linked immunosorbent assays (ACE)), which was more than the required five animals from a single management group (The Scottish Government, 2014). These were home-bred heifers, weaned at the new farm in October 2011 and moved to the home farm in March 2012, when they were tested. Out of these 13 animals, one tested positive for antibodies to BVDV. Following the advice of the veterinary surgeon at the time, in September 2012 all calves were tested for BVDV antigen (blood reverse transcription polymerase chain reaction (RT-PCR)) to try to identify a PI. This test was delayed to fit with the farmer's management schedule. A month before the September follow-up test was performed, seven cows with calves at foot had been purchased. The farm of origin of these animals had already performed an antibody check test BVD test under the Scottish eradication scheme. However, the bought-in calves were tested with the rest of the calves and a PI calf was found within the bought-in group. Cows were given a presumed BVD antigen negative status if their calves tested negative. After finding the first PI, the affected calf and its dam were isolated. They were brought to the home farm and kept at grass in a small paddock with access to shelter and straw bedding. No follow-up bloods were performed on the calf as it was ill thriven and was showing clinical signs of being persistently infected with BVD, while the dam tested negative for antigen. This calf was treated on farm for pneumonia, initially with long-acting oxytetracycline and later with florfenicol, without improvement and was referred to the Scottish Centre for Production Animal Health and Food Safety (SCPAHFS) on 3rd October 2012. Blood samples were taken on admission of the animal and the PI status of the calf was confirmed on antigen testing.

The farm started following a BVD vaccination protocol in October 2012 with the use of an inactivated vaccine (Bovilis ® MSD Animal Health). It was acknowledged that the timing of this vaccination was not as per datasheet recommendations (primary course completed no less than four weeks before the start of gestation) but the first opinion veterinarian was worried about compliance with the vaccination protocols if the vaccine was to be administered during the summer grazing period. Since 2013 all replacement heifers receive a primary immunisation in January with a second dose four weeks later to ensure that protection is given well before the entry of the bulls in April. At the same time cows receive a booster. Boosters are given in

October only to those cows and heifers scanned in calf. Non-pregnant cows are sold and bulls are not vaccinated. The farm also planned to test all calves born in 2013 for antigen with tissue tags, which is a practice that has continued thereafter.

During the 2013 season, there was one abortion; however, no diagnostic work-up was performed and therefore this could not be definitively attributed to BVD. In the same season, six antigen positive calves were identified on tissue testing, but no follow-up tests were performed to confirm their PI status (they were assumed to be PIs). As with the first PI identified in 2012, in 2013 all PIs and their dams were isolated at the home farm. These dams were not tested since they had antigen-negative calves the previous season and were assumed negative. Two out of this group of six PIs were admitted to the SCPAHFS in March and May 2013, when they were two and six weeks old respectively. There were no records of BVD tests for the calf admitted in March at the SCPAHFS. The calf referred in May tested antigen positive on blood taken on admission. The farmer made the decision to keep two of the other PI calves in isolation at the home farm. These were animals that looked ´normal´ and were growing well. In an attempt to get them to slaughter weight, the farmer took them off their mothers and hand-reared them. They continued to thrive until one developed pneumonia, at which point they both rapidly deteriorated. The farmer attempted treatment with penicillin and observed a slight improvement, but the pneumonia relapsed a month later. These two animals were referred to the SCPAHFS in October 2013, at six months of age. Both animals were tested for BVD on admission at the SCPAHFS and were confirmed antigen positive. The remaining two of the six calves that tested antigen positive died on farm.

As of 2013, all bought-in female stock and calves at foot were isolated and tested for BVDV antigen prior to mixing with the herd. A total of 40 bulling and in-calf heifers were bought in that year, all of which were found to be free of BVDV. After this point, the farmer decided not to buy in any more stock apart from breeding bulls. Currently, the farmer relies on the bull breeder's BVDV test and the bulls are not isolated.

In 2014, all calves continued to be tissue tag tested. Two calves tested positive for BVD, one of which was born from one of the 2013 bought in in-calf heifers. These two calves were re-tested

on blood and subsequently found to be BVD negative. The farm achieved a BVD negative status in the same year and has maintained it since then. In 2015, all calves were tissue tag negative. The farmer had hoped to be able to stop tissue-testing all the calves and rely solely on the check test. However, discussion with his veterinarian has convinced him to continue tissue testing, especially considering the potential risks of expanding the herd and having increased contact with neighbours at the home farm.

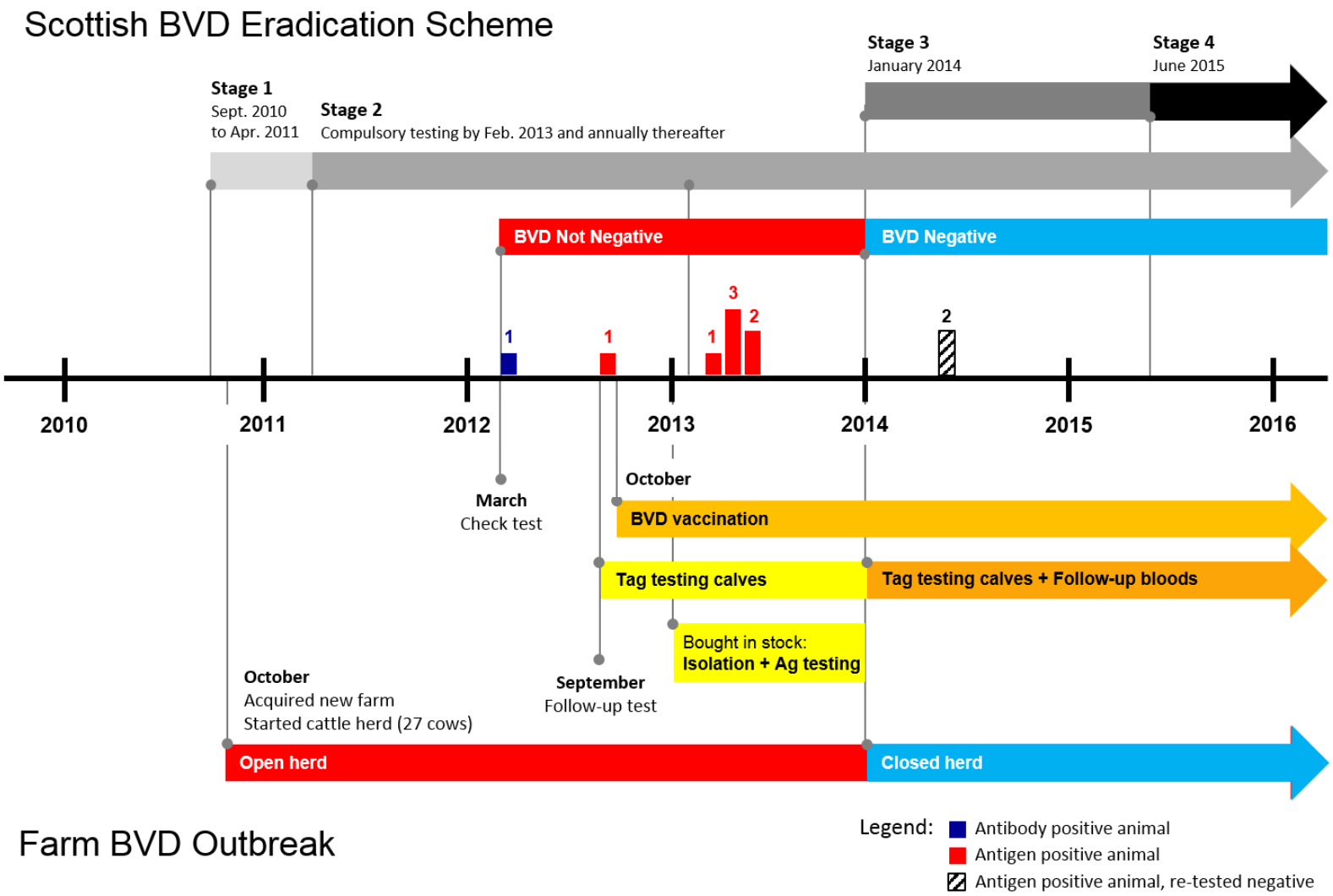


Figure 6.1 Timeline of the BVD outbreak at the farm in comparison with the progression of the Scottish BVD Eradication Scheme.

6.4. Herd health impact of the outbreak

No herd health issues were appreciated in the herd by the farmer during the BVD outbreak. They were happy with the percentage of cows confirmed in calf. There was no record of weak or stillborn calves and no increases in calf losses were detected. Table 6.1 summarises the number of cows put to the bull, the percentage of barren cows and the percentage of reared calves for 2011-15 in relation to the targets recommended by Fertbench, the suckler herd fertility benchmarking service offered by the Scottish Agricultural College (SAC) Consulting (Quality Meat Scotland, 2010). In the season that BVDV was introduced to the farm (2012-13), the seven lost calves corresponded to the seven BVD PIs identified on farm. In 2014-15 there was an increase in the percentage of barren cows, a decrease in the number of calves reared to sale point and more cases of calf diarrhoea. However, given that BVD had been eradicated from the farm, these were not investigated further. The farmer did observe that PI calves were prone to pneumonia. In addition, the farmer mentioned that if he/she had not kept the two 'healthy' PI calves and tried to rear them, only for them to deteriorate, they may subsequently have struggled with the concept of culling an animal just because it is a PI.

	Farm values				**Target**[2]		
Calving season	**2011-12**	**2012-13**[1]	**2013-14**	**2014-15**	**Top**	**Bottom quarter**	**Average**
Number of cows put to the bull	65	68	116	128			
Number of cows and heifers scanned in calf	59	64	107	110			
Barren cows (%)	9	6	8	14	≤ 5		
Calves reared (%)	80	84	85	77	93	79	88

Table 6.1 Summary of pregnancy rates and calf losses per season from 2011 to 2014. [1]Year of the BVD outbreak. [2](Quality Meat Scotland, 2010)

6.5. The cost of the outbreak

The biggest cost of the BVD outbreak on this farm was considered to be associated with culling of PI animals. The farmer estimated the overall cost at £7,600. This includes loss of stock, testing of animals and labour, but does not include the cost of adding electric fences at the new farm, the extra bedding, feed and work of keeping animals isolated. Currently, the farm is spending around £650 a year in the continued testing of calves and £490 in vaccines, which results in £10.40 per cow per year in a 110 cow herd.

6.6. Farmer perceptions

Regarding BVD understanding, the farmer mentioned that prior to the BVD outbreak they he/she was aware of the acronym but had no understanding of what it was or what it meant. This was partially due to the farm historically being a sheep flock, but also because they had no previous experience with the disease. Information about BVD came from the farm's veterinary practitioners, speaking to fellow producers and articles in the farming press. When asked if he/she considered having a BVD negative herd status represented a benefit when selling animals, the overall feeling was that there was minimal interest from the store market as to BVD status. The farmer's perception is that the market's primary focus is on pneumonia. No breeding heifers were sold while the farm had a non-negative status. However, the general comment was that a non-negative status made no difference to the sale value in the industry.

6.7. Discussion

Case studies in relation to the control of BVD have been published before. In a series of interviews published on the Scottish Government's website (The Scottish Government, 2013a), the experiences of six farmers were presented. In most cases, the interviewed farmers were aware of BVD before the Eradication Scheme started, mainly due to participation in Health

Schemes or disease investigations. Similarly, Animal Health Ireland (Animal Health Ireland, 2016) interviewed four farmers who had made efforts to eradicate BVD in their herds before the national Irish programme was launched in 2012. By contrast, the farm presented in this study only initiated testing for BVD when it was required by the Scottish BVD Eradication Scheme and the farmer was not aware of the disease prior to this testing. Case studies presented by the Scottish Government and AHI reported that farmers noted poor growth rates in calves, increased susceptibility to infection, greater mortality and reduced fertility. The farmer in this study noticed that PI animals were more susceptible to respiratory disease, which is recognised as one of the main complications of BVDV infection (Ridpath, 2010). However, the outbreak had little perceived effect on the overall herd's productivity. In the year of the BVD outbreak the percentages of barren cows and reared calves were not worse than in other years. Overall, the farm values are between the bottom quarter and the average Scottish beef suckler herd, according to Quality Meat Scotland data (Quality Meat Scotland, 2010). Worse rates were observed in this herd in 2014-15. These, in addition to BVD, can be affected by a multitude of factors and were not investigated further. The consequences of BVDV infection in a herd depend on the virus strain involved, the herd organisation and the animals' immune status (Gates, Humphry, et al., 2013). The fact that, due to compulsory testing, PI calves were quickly detected, isolated and removed from the herd was key for the success of controlling BVD in this herd.

Buying animals into a herd from external untested sources has been recognised as one of the main risks for introduction of BVD to a herd (Graham et al., 2013), and the risk is higher when the introduced animals are cows with calves at foot or pregnant dams (Gates et al., 2014). This was the route of introduction of the first PI in this herd. What is interesting about this outbreak is that the group of 13 heifers with the initial positive check result in March 2012 did not have contact with the calf that was subsequently identified as a PI (this calf didn't arrive on farm until August 2012). The source of the antibody positive result in the 2012 check test was not confirmed. It remains a possibility that the animal seroconverted after being transiently infected by nose-to-nose contact with infected neighbouring cattle indicating another potential source of virus over and above bought-in animals (Ersbøll et al., 2010; Graham et al., 2016). To avoid this contact, electric fences were added to the existing boundary fences at the new farm, where adult cattle and calves are kept most of the time. At the home farm, the farmer is now keeping pregnant

heifers away from fields that have contact with neighbour's cattle. The circumstances of the check test performed at the farm of origin of the bought-in PI are unknown. However, it is important to emphasize the fact that when performing antibody check tests, it is essential to correctly identify and sample separate management groups. Otherwise there is risk to miss antibody positive animals and the source of infection.

Following the identification of antigen positive animals from the calf screen test in September 2012 and the instigation of tag testing all calves in 2013, antigen positive animals were identified. This case study indicated that many of these antigen positive animals were only tested for antigen once. Given that a single antigen detection test cannot differentiate between transiently infected (TI) or PI animals (Dubovi, 2013), follow-up tests are recommended for each antigen positive result, at least three weeks after the initial sample (Lanyon et al., 2014; The Scottish Government, 2015b). These were only performed on five out of the seven antigen-positive calves (on farm or at the SCPAHFS). Therefore, it remains a possibility that the remaining two calves were not persistently but only transiently infected due to exposure to comingling PI calves. Animals TI can also successfully transmit BVDV (Lindberg and Houe, 2005); however, it is not necessary to remove them from the herd in an eradication programme. Removing TI animals as a result of inadequate testing would result in farmers losing money in terms of unnecessary culling of animals. At this farm, since 2014, all the calves are tag tested and follow-up blood tests are performed when required. After eradicating BVDV from a herd, monitoring is essential to react against new incursions of the virus (Lindberg and Houe, 2005) and although tag testing all the calves may have higher associated costs than antibody check tests, it allows faster detection of BVDV in the herd and has a higher cost-benefit margin (Santman-Berends et al., 2015).

The brief cost analysis in this study was based on the farmer's estimates; therefore, the cost is likely to be inaccurate but allows some comparisons with values published in the literature. The cost of the present outbreak was estimated as £7,600 (£126.67 per cow, herd of 60 cows) in one year and the farmer is currently spending £1,140 in monitoring and vaccinating for BVDV. This estimate is higher than those reported in the Scottish Government case studies, where the costs due to losses and control of the outbreaks ranged between £1,010 to £4,317 for a 150 cattle beef

herd (£6.31 and £28.78 per animal respectively) (The Scottish Government, 2013b; The Scottish Government, 2013c), although the scenarios presented were mainly based on farms endemically infected with BVD. Regarding the cost of continuous monitoring and control measures for the disease, prior to launching the Eradication Scheme, the Scottish Government estimated the costs of controlling BVD in the first year of the Scheme in £1,629 for a Less Favoured Area (LFA) cattle and sheep farm (The Scottish Government, 2010a), which is a higher value compared to the annual £1,140 spent at the present farm. The latter represents a cost of £10.40 per cow per year for a herd of 110 cows. In 2004, the losses associated with BVD in an endemic Scottish beef suckler herd were calculated at £37 per cow per year (Gunn et al., 2004). Compared to this value, the present farm could be considered to be saving £26.60 per cow per year in BVD-associated losses compared to a herd in which the disease is uncontrolled.

This case study confirms the importance of many issues in relation to the control of BVD. These include the implementation of a national eradication programme to raise farmer's awareness of the disease, appropriate follow-up testing of antigen positive animals, prompt removal of PI animals and implementation of appropriate biosecurity, vaccination and on-going monitoring measures. Had the PI animals on this farm not been identified (in response to further testing required by the Scottish Government BVD eradication scheme) the impact of the disease could have been much greater for the health, welfare and productivity of this farming enterprise.

7. General discussion

Animal health surveillance is an essential activity that helps to protect animal health and welfare, public health and international trade and the economy. New threats to animal and human health have been a constant in history and will continue to emerge; therefore, surveillance systems need to constantly adapt to this changing environment. To ensure that systems are efficient and fit for purpose, reviews and evaluations of surveillance activities are becoming more frequent. In the United Kingdom (UK) the entire veterinary surveillance strategy was reconsidered after the 2001 Foot-and-mouth (FMD) outbreak (Department for Environment Food and Rural Affairs, 2003) and this devolved in later reviews of the provision of surveillance in England and Wales and Scotland. The final report of the review of veterinary surveillance – 'The Kinnaird Report', was published by the Scottish Government in 2011. The document recognised the need for more cost-effective approaches to surveillance and recommended the inclusion of existing animal health data streams in the existing system. In this context, this thesis aimed to evaluate the usefulness of the Scottish Centre for Production Animal Health and Food Safety (SCPAHFS) caseload as a source of passive surveillance data.

Passively obtained surveillance data always come with a degree of bias, especially if data are not primarily collected for surveillance purposes (Sorensen et al., 1996). Samples are more likely to be submitted to the Veterinary Investigation Diagnosis Analysis (VIDA), the main passive surveillance system in the UK, when diseases cause acute signs, cause higher losses in the herd or flock and animals are valuable enough to pay for the testing (Watson et al., 2008; Animal and Plant Health Agency, 2014d). In the case of the SCPAHFS, the caseload is biased towards chronic and uneconomic cases, given the way the clinic is organised. Clear structural differences exist between VIDA and the SCPAHFS and the results of the second study strongly suggested that the SCPAHFS caseload represents a part of the livestock population that is not currently captured by VIDA. In addition, the caseload covered similar regions to the Scotland's Rural College (SRUC) Ayr and Dumfries DSCs. Therefore, the SCPAHFS could complement surveillance activities in these regions. The number of cases received at the centre is smaller than the samples submitted to DSC or VI centres; however, information from these cases would

otherwise be missed. Due to their low economic value, animals referred to the SCPAHFS would otherwise be collected by fallen stock services and, since post-mortem examinations are not routinely performed at these centres, their information would be missed (Lovatt and Strugnell, 2013). Additionally, given that the SCPAHFS caseload is already used for teaching and research purposes, this represents a cost-effective source.

The relationship between the SCPAHFS and the first opinion farm animal practitioners is very important to guarantee the flow of cases into the centre. Clinicians at the SCPAHFS make sure that feedback on the cases is given to both farmers and veterinarians, by phone call and a summary letter posted to the veterinarian. However, a regular report or summary of the cases received at the SCPAHFS is not currently being produced. Publishing this type of report would be beneficial to referring farmers and practitioners and would provide additional information on the endemic conditions that affect livestock in their regions.

Regardless of whether or not a final diagnosis was reached, each case admitted to the SCPAHFS generates clinical data that could be used for research and surveillance purposes. Examples of conditions that have been studied using the SCPAHFS caseload include cardiac disease in cattle, bluetongue, malignant catarrhal fever and mucosal disease and kangaroo gait in ewes (Clements et al., 2002; Bexiga et al., 2007; Bexiga et al., 2008). The third study in this thesis was designed with the aim of making use of the additional information generated by the SCPAHFS caseload, with emphasis on bovine viral diarrhoea (BVD). Due to its economic impact, BVD is currently the focus of control programmes in several European countries (Volker Moennig et al., 2005; Stahl and Alenius, 2012). In Scotland the BVD Eradication Scheme was launched in 2010 and since then over 4,700 PI animals have been identified. Analysis of the clinical presentation of BVD PIs admitted to the SCPAHFS over the last ten years has shown that cases admitted after the eradication scheme started tended to be younger and presented less clinical disease, indicating that PIs are being detected and removed at earlier stages in disease, reducing the chances to transmit the virus. These findings highlight some of the elements of success of the eradication scheme. As the scheme progresses and the levels of circulating BVD virus decrease, identifying BVD infection based on clinical findings will no longer be viable. Detecting infection will become more difficult and the risks associated with missing infected animals will

increase, which emphasises the importance of carrying out active surveillance for the disease, as exemplified by the case study.

A common issue in the three first studies was the lack of standardisation and incompleteness of the data recorded in the original spreadsheets. These are some of the most common constraints to adding data from secondary sources to surveillance systems (Lind et al., 2012; Velasova et al., 2015). Data cleaning was a big part of the data collation process for these studies. The information that the spreadsheets missed is available; however, the lack of coordination between three different recording systems that are in different formats (paper and electronic records) makes the process of collating data more time consuming, which was the reason why the final diagnoses reached at the SCPAHFS were only analysed in the second study. The main improvement needed at the SCPAHFS to make the most of the data generated by the caseload is the instigation of a new recording system. This would need to use pre-populated fields, with standardised nomenclature that minimises common typing mistakes with free-text entry.

There is potential to study the clinical presentation of many other conditions referred to the SCPAHFS (e.g. ovine pulmonary adenocarcinoma and Johne's disease). The use of improved recording methods would facilitate this research. Keeping the animals' case files in electronic records would also make the task of publishing a regular report on the conditions diagnosed at the centre much easier.

The SCPAHFS is a source of animal health data that has potential to provide information for surveillance purposes, with emphasis on endemic and chronic conditions in cattle and sheep from Central and South West Scotland. However, the existing data collation and recording methods need to be improved.

Appendices

Appendix 1: Referring veterinary surgeon and farmer history forms

SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH AND FOOD SAFETY
University of Glasgow School of Veterinary Medicine, Bearsden Road, Glasgow G61 1QH
NEW CASE HISTORY

Date …….. **Clinician……..**

REFERRING VETERINARY SURGEON	
Name	
Name of Practice	
Address	
	POST CODE
Telephone number	
Presumptive diagnosis	
Signalment	Species Breed Age Sex Neutered ☐
Presenting signs **i) General condition**	
ii) Specific clinical signs	
Clinical history **i) Date *first seen* by vet?**	
ii) Previous illnesses & relevant production details for this animal (scour, pneumonia, lameness, date of calving etc.)	
iii) Previous disease history on farm? (young stock, adult stock, other animals)	
Only animal affected ?	Yes ☐ No ☐ If no, number affected ……
Treatment given & Response?	
Date animal *last seen* by vet	
Is the animal fit to transport ?	Yes ☐ No ☐
Herd health status (member of accreditation scheme?)	
Vaccination status of farm	None used ☐ BVD ☐ brand:…… Leptospirosis ☐ brand:…… Rotavirus ☐ brand:…… Respiratory vaccines ☐ brand:…… Other ……
Additional information continues overleaf	

SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH AND FOOD SAFETY
University of Glasgow School of Veterinary Medicine, Bearsden Road, Glasgow G61 1QH

NEW CASE HISTORY

ADDITIONAL HISTORY AND INFORMATION

SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH AND FOOD SAFETY
University of Glasgow School of Veterinary Medicine, Bearsden Road, Glasgow G61 1QH

NEW CASE HISTORY

FARMER	
Name	
Address (incl post code)	
	POST CODE
Telephone number (Including code)	Home Mobile
ANIMAL DETAILS (if not already complete)	Species Breed Age Sex Neutered ☐
Presenting signs	
Clinical history **i) Duration of current problem?**	
ii) Previous illnesses in this animal? (scour, pneumonia etc)	
iii) Production data for animal (date of calving/lambing, milk yield etc.)	
iii) Previous disease history on farm? (young stock, adult stock, other animals)	
Treatment given to this case?	
Only animal affected ?	Yes ☐ No ☐ If no, number affected ……
	No animals in the same group as the affected animal……..
FARM DETAILS	Type…….. Number of animals……
	Other species on the farm? (& numbers)
	Beef ☐…..…….. Pigs ☐……
	Dairy ☐…….. …. Other ☐……..
	Sheep ☐…….. ….
Herd status	Closed ☐ Open ☐ Do you buy in bulls/rams ? Yes ☐ No ☐
Vaccination status of farm	None used ☐
	BVD ☐ brand:……
	Leptospirosis ☐ brand:……
	Rotavirus ☐ brand:……
	Respiratory vaccines ☐ brand:……
	Other ……..

SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH AND FOOD SAFETY
University of Glasgow School of Veterinary Medicine, Bearsden Road, Glasgow G61 1QH

NEW CASE HISTORY

Anthelmintic usage on farm	Calves Pour on ☐ Injectable ☐ Bolus ☐ Brand …… Young stock Pour on ☐ Injectable ☐ Bolus ☐ Brand …… Adult cattle Pour on ☐ Injectable ☐ Bolus ☐ Brand …… Lambs Pour on ☐ Injectable ☐ Drench ☐ Brand …… Adult sheep Pour on ☐ Injectable ☐ Drench ☐ Brand …… When dosed?…… …… Do you treat for fluke? Yes ☐ No☐ Product used……
Grazing type and practice (tick all that apply)	Hill ☐ Upland ☐ Lowland ☐ Zero-grazed ☐ Rotational ☐ Set-stocked ☐
Current housing & feeding of affected animal (grass, silage, TMR etc)	Housed ☐ At Grass ☐
Basic details of current ration & feeding practice (tick all that apply)	Grass ☐ Grass silage ☐ Maize silage ☐ Buffer feed ☐ In-parlour feed ☐ TMR ☐ Self-feed ☐ Recent Change of feeding (i.e. turned out or just housed ?) yes ☐ no ☐ Details……
Minerals (status, suppl. given?)	Trace element bolus ☐ Ad-lib blocks ☐ Other ☐ (details)……
Price agreed	£
Transport arranged	Yes ☐ No ☐ Date due in ……

ADDITIONAL INFORMATION

Appendix 2: Farmer consent form

University of Glasgow | School of Veterinary Medicine

DONATION OF FARM ANIMALS TO THE SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH & FOOD SAFETY, UNIVERSITY OF GLASGOW

Dear Benefactor,

Thank you for donating your animal(s) to the Scottish Centre for Production Animal Health and Food Safety. We are very grateful to you as this will enhance our students' exposure to clinical material. We have a responsibility to make you aware that any farm animals donated to us will not be returned to the farm of origin and that any clinical or other data gathered from the animal/s may be used for research purposes. If data from this case is used for research purposes it will be completely anonymised.

Please complete the section below:-

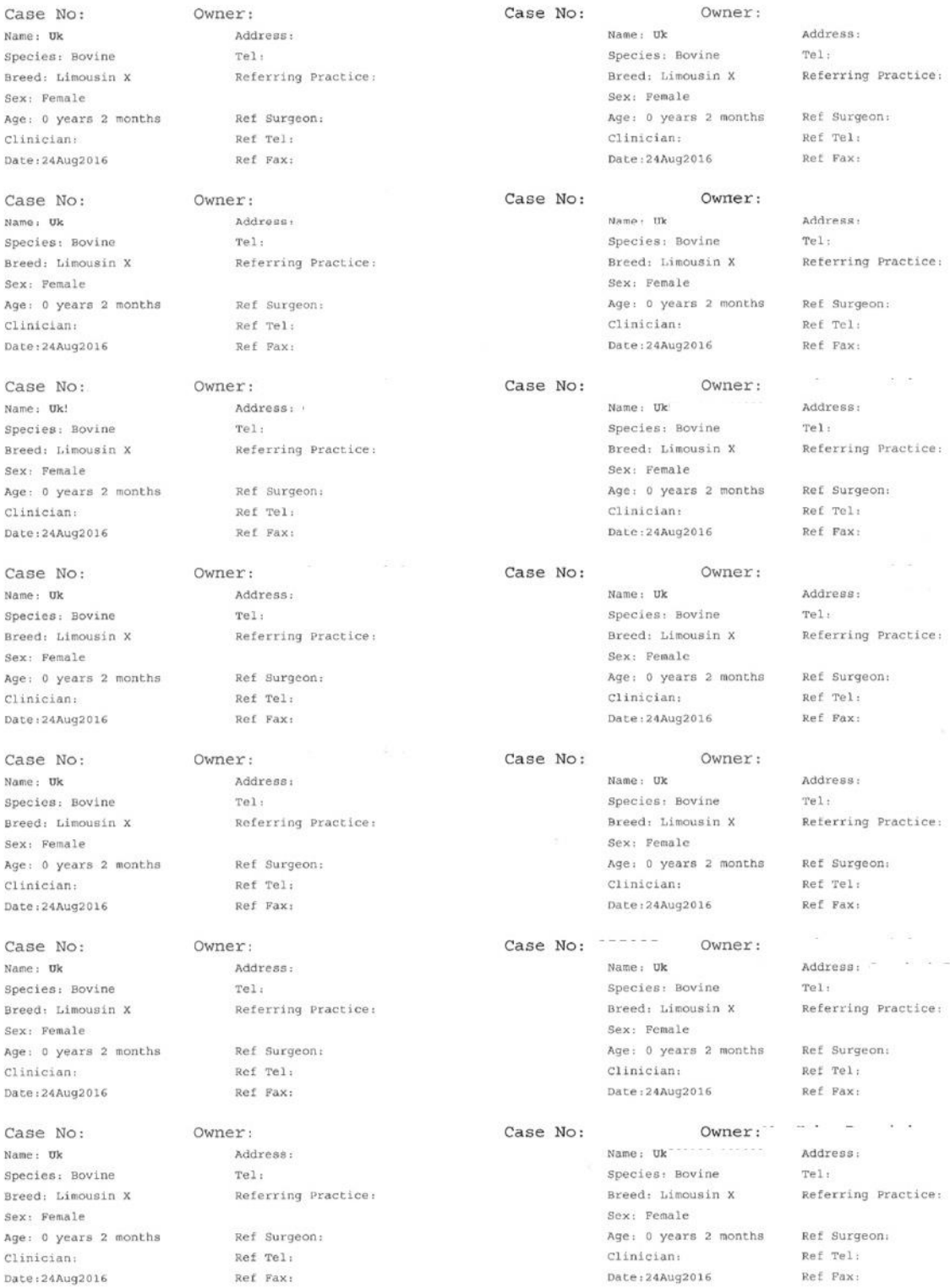
Ear Tag	**Species** Cattle/Sheep	**Breed**	**Sex** M/F	**DOB**	**Age**

As the owner/agent of the above animal/s I certify that I am donating them to Glasgow University. I understand that the animal/s will become property of Glasgow University and will not be returned. I also consent to data associated with the case being anonymised and potentially used for research purposes.

Name of Benefactor			
Address			
Signature		**Date**	

For donated teaching cases only, a fixed fee of £40 per Bovine and £20 per Ovine will be paid to the owner as a gesture of goodwill; this is because we are aware that taking a detailed history and arranging collection takes extra time. This donation is made on a per collection basis not on a per-animal basis, and is not intended to reflect the market value of the animal(s) donated. Arrangements for invoicing must be made via telephone conversation prior to uplift of the animal(s); no payment will be made at the time of collection. Please provide an invoice on letter headed paper, or complete the attached invoice template at the time of collection.

Appendix 3: Case labels



Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk!
Species: Bovine
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Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Case No:
Name: Uk
Species: Bovine
Breed: Limousin X
Sex: Female
Age: 0 years 2 months
Clinician:
Date:24Aug2016

Owner:
Address:
Tel:
Referring Practice:
Ref Surgeon:
Ref Tel:
Ref Fax:

Appendix 4: Clinical examination form

SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH AND FOOD SAFETY
University of Glasgow School of Veterinary Medicine, Bearsden Road, Glasgow G61 1QH

CLINICAL EXAMINATION SHEET

Case Number: _____ **Ear Tag Number:** _____
Clinician: _____ **Date:** _____

Subjective

Breed: _____ **Sex:** _____ **Age:** _____ **Weight (kg):** _____ **Body Condition Score:** _____

Conformation_____

Demeanor_____

Objective

Temperature	°C	°F

Cardiovascular **Heart Rate (beats/min):** _____

Capillary refill time (seconds)					Additional comments if abnormal
Pulse character	normal		weak		
Rhythm	regular		irregular		
Heart sounds	normal		muffled		
	murmur		Pericardial sounds		
Thoracic percussion	normal		↑ ventral dullness		
Oral mm	normal		pale		
	icteric		cyanosed		
	petechiae		congested		
Vaginal MM	normal		pale		
	icteric		cyanosed		
	petechiae		congested		
Venous distension	none		jugular		
			mammary		
Oedema	none		Pre-sternal		
	ventral		Sub-mandibular		
	limbs		ascites		
Exercise intolerance	none		present		

Respiratory **Respiratory Rate (breaths/min):** _____

					Additional comments if abnormal
Resp. character	normal		hyperpnoea		
	dyspnoea		Grunt		
Coughing	none		occasional		
	frequent				
Nasal discharge	none		present		
Breath odour	normal		halitosis		
Auscultation	normal		harshness		
	squeaks		URT sounds		
Percussion	normal		↑ resonance		
	pain		cough		
Thoracic pain	none		present		

Musculoskeletal

					Additional comments if abnormal
Skeleton	normal		abnormal		
Head & ears	normal		abnormal		
Joints	normal		abnormal		
Feet	normal		abnormal		
Gait	normal		abnormal		
Skin	normal		alopecia		
	ringworm		lice		

Photograph(s) taken: ☐ **(Whole animal lateral/profile & lesion detail if appropriate)**

Signifigant Findings

Differential Diagnoses

Plan

Appendix 5: Clinical progression (TPR) sheets

SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH AND FOOD SAFETY
University Of Glasgow School of Veterinary Medicine
Bearsden Road, Glasgow G61 1QH

Case Label

PROGRESS / TREATMENT RECORD

Date & Time	Clinical Findings	Progress / Diagnostic testing undertaken / Treatment & Comments		Clinician
	T P R	Biochem ☐ Haem ☐ Urinalysis ☐ Faecal samples: Bacto ☐ Parasitology ☐ Milk samples bacto ☐ Serology ☐ Radiography ☐ Other ☐ …… ……		
		Drugs used & amount	**Batch No.**	
Date & Time	**Clinical Findings**	**Progress / Diagnostic testing undertaken / Treatment & Comments**		**Clinician**
	T P R	Biochem ☐ Haem ☐ Urinalysis ☐ Faecal samples: Bacto ☐ Parasitology ☐ Milk samples bacto ☐ Serology ☐ Radiography ☐ Other ☐ …… ……		
		Drugs used & amount	**Batch No.**	

PAGE……

Appendix 6: Additional results form

SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH AND FOOD SAFETY
University of Glasgow School of Veterinary Medicine, Bearsden Road, Glasgow G61 1QH

ANCILLIARY TEST RESULTS: Weights , Parasitology, etc

Date	Test	Results

Appendix 7: Communication record form

SCOTTISH CENTRE FOR PRODUCTION ANIMAL HEALTH AND FOOD SAFETY
University of Glasgow School of Veterinary Medicine, Bearsden Road, Glasgow G61 1QH

REFERRING VET/FARMER COMMUNICATION RECORD

Date & time	Name & occupation (vet or farmer) of person contacted	Phone no. called	Summary of conversation (use as many lines as necessary)	Clinician
Date	Report letter sent to vet & copy included in file ☐			Clinician
Date	Post Mortem report sent to vet (this is not usually done) ☐ & copy included in file ☐			Clinician

PAGE ……(Use additional pages as necessary)

Appendix 8: Example of biochemistry and haematology results

Sample No [redacted] Lab Ref [redacted]

University of Glasgow

School of Veterinary Medicine

CLINICAL PATHOLOGY REPORT

Veterinary Diagnostic Services, School of Veterinary Medicine
College of Medical, Veterinary and Life Sciences
University of Glasgow, Bearsden Road, Glasgow G61 1QH, UK
Tel: +44 (0)141 330 5777 Fax: +44 (0)141 330 5748
email: vet-sch-vds@glasgow.ac.uk Website: www.glasgow.ac.uk/vds
University of Glasgow, charity number SC004401

[redacted]
FARM ANIMAL MEDICINE & TEACHING(12393)
University of Glasgow
Veterinary School
Bearsden
GLASGOW
159

Your Ref
Owner [redacted]
Animal **UK[redacted] Hosp No [redacted]**
Species CATTLE
Breed HOLSTEIN
Age 3 m 4 w
Sex F

Sample No [redacted] **Lab Ref** [redacted]
Sample **EDTA, hep blood**
Reason **In poor BCS, QAR, loose faeces, tongue tip ulceration/necrosis,hars**

Sent **31/07/2014**
Received **31/07/2014**
Report Date **01/08/2014**

Test	Result	Unit	Reference Range
022 - Ruminant Profile			[redacted]
Sodium	**139.0**	mmol/l	135 - 151
Potassium	**4.9**	mmol/l	3.2 - 5.8
Sodium:Potassium Ratio	**28.4**		
Chloride	**101.5**	mmol/l	96 - 111
Calcium	**2.30**	mmol/l	2.2 - 3.3
Phosphate	**1.80**	mmol/l	1.13 - 2.84
Magnesium	**0.72**	mmol/l	0.65 - 1.39
Urea	**3.7**	mmol/l	- 8.3
Creatinine	**37**	umol/l	53 - 132
Total Bilirubin	**36**	umol/l	- 8
ALK Phos	**565**	U/l	20 - 280
AST	**136**	U/l	- 140
GGT	**119**	U/l	- 27
Total Protein	**59**	g/l	52 - 84
Albumin	**28**	g/l	21 - 34
Globulin	**31**	g/l	29 - 56
Albumin:Globulin Ratio	**0.90**		
GLDH	**53**	U/l	- 10
005 - Haem - Full w.profile			[redacted]
RBC	**3.59**	x10 E12/l	5.0 - 10.0
Hb	**5.5**	g/dl	8.0 - 15.0
HCT	**17.4**	%	24 - 46
MCV	**48.5**	fl	40.0 - 60.0
MCH	**15.5**	pg	11.0 - 17.0
MCHC	**31.9**	g/dl	30.0 - 36.0
RDW	**32.4**	%	
WBC	**8.11**	x10 E9/l	4.0 - 12.0
WBC	**13.74**	x10 E9/l	4.0 - 12.0
Neutrophils	**5.839**	x10 E9/l	0.6 - 4.12
Lymphocytes	**1.622**	x10 E9/l	2.5 - 7.5
Monocytes	**0.568**	x10 E9/l	0.025 - 0.84
Eosinophils	**0.081**	x10 E9/l	0.00 - 2.40
Basophils	**0**	x10 E9/l	
PLT	**1173**	x10 E9/l	100 - 800
MPV	**7**	fl	

Sample No [redacted] Lab Ref [redacted]

PCT	**0.82**	%
PDW	**68.2**	%

Haematology Smear Report

The red cells show spiculing with several acanthocytes present..

END OF REPORT

Total Cost exc. VAT [redacted]

Appendix 9: Example of post-mortem report

Sample No [redacted]

University of Glasgow

School of Veterinary Medicine

PATHOLOGY REPORT
Postmortem Examination

Veterinary Diagnostic Services, School of Veterinary Medicine
College of Medical, Veterinary and Life Sciences
University of Glasgow, Bearsden Road, Glasgow G61 1QH, UK
Tel: +44 (0)141 330 5777 Fax: +44 (0)141 330 5748
email: vet-sch-vds@glasgow.ac.uk Website: www.glasgow.ac.uk/vds
University of Glasgow, charity number SC004401

[redacted]
FARM ANIMAL MEDICINE & TEACHING(12393)
University of Glasgow
Veterinary School
Bearsden
GLASGOW

159

Your Ref	[redacted]
Owner	[redacted]
Animal	**UK** [redacted] **Hosp No** [redacted]
Species	CATTLE
Breed	HOLSTEIN
Age	5 y 0 m
Sex	F

Sample No	[redacted]	Sent	**15/08/2014**
Clinical Diag	**?? Fluke, Johne's, liver abscess, peritonitis?**	Received	**18/08/2014**
Slides		Report Date	**18/08/2014**

Clinical History
Farm has had a few cows not doing well - unsure if related conditions. This cow is 4th lactation, low mild yield, been dry since June. Should be in calf. Has had liver biochem done previously suggesting liver damage. Treated with fluikicide at drying off. Farm has got history of Johne's positive cows on milk testing. On arrival at GUVS - dull, dehydrated, profuse watery diarrhoea, inappetent. Given oral fluids last night but worse today and recumbent.

Gross Pathology
This is the carcass of an 8 year old (per history) female Holstein-Friesian cow in moderate body condition and with mild autolysis.

Upon opening the abdominal cavity, several extensive fibrous adhesions are observed between the hepatic capsule and the reticulum. In between the adhesions, a large (20x30x30cm approximately) fibrosed-encapsulated nodule containing large amount of pus is observed (abscess).

The liver is mildly friable and mild pale to orange. The bile ducts are mild to moderately prominent, with moderately thickened walls and containing mildly viscuous, yellowish bile. There are low numbers of multifocal areas of capsular and parenchymal scarring.

Morphological Diagnosis
Morphologic diagnosis 18/08/14:

Abdominal cavity; intra-abdominal abscessation, severe, chronic

Liver; mild, chronic, multifocal cholangiectasia and cholangitis

Comment
Comments 18/08/14: In this case, the most likely cause of the deterioration was the presence of a large intra-abdominal abscess. The location and adhesion to the reticulum and the visceral aspect of the liver might indicate a penetrating (e.g wire), traumatic injury from the reticulum, however, the causative agent nor the track were found. The cow was in advanced calf and the abdominal pressure and displacement of organs that the placenta causes during pregnancy did likely worsened the situation.

Adult hepatic parasites were not found in the liver but the thickening of the hepatic bile ducts indicate more recent, previous infection.

This is a final report.

Appendix 10: Referral reasons of the 2006-15 caseload

Referral Reason	Cattle	Sheep	Pigs	Alpacas	Goats	Total	Total %
Affections of body weight and/or size	97	65	2	0	0	164	8.4
Pneumonia	124	14	9	0	0	147	7.6
Johne's disease	97	41	0	0	0	138	7.1
OPA	0	83	0	0	0	83	4.3
Denta or mandibular abnormalities	3	70	0	0	0	73	3.8
Healthy animal	25	29	18	0	0	72	3.7
Diagnosis not recorded	30	26	10	0	0	66	3.4
BVD PI	64	0	0	0	0	64	3.3
Diarrhoea	56	4	2	0	0	62	3.2
Cull animal	6	36	11	0	0	53	2.7
Displaced abomasum	51	0	0	0	0	51	2.6
Lameness	26	19	0	0	0	45	2.3
Pericarditis	43	0	0	0	0	43	2.2
Mastitis	21	19	0	0	0	40	2.1
Arthritis, Polyarthritis	18	17	3	0	0	38	2.0
Congenital abnormalities	31	5	1	0	0	37	1.9
Neurological deficits	18	16	2	0	0	36	1.8
Peritonitis	29	1	0	0	0	30	1.5
Endocarditis	26	1	0	0	0	27	1.4
Traumatic reticulopericarditis/peritonitis (Wire disease)	21	0	0	0	0	21	1.1
Spastic paresis	19	0	0	0	0	19	1.0
Metritis, Endometritis, Pyometra	16	2	0	0	0	18	0.9
Pre-96 animal	18	0	0	0	0	18	0.9
Bloating	15	1	0	0	0	16	0.8
Lymphoma, Lymphosarcoma	16	0	0	0	0	16	0.8
Heart failure	15	0	0	0	0	15	0.8
Heart murmur	14	1	0	0	0	15	0.8
Malignant catarrhal fever	14	0	0	0	0	14	0.7
Fracture	5	7	1	0	0	13	0.7
Liver fluke	7	6	0	0	0	13	0.7

Referral Reason	Cattle	Sheep	Pigs	Alpacas	Goats	Total	Total %
Portocaval thromboembolism	13	0	0	0	0	13	0.7
Hernias - Umbilical	9	0	3	0	0	12	0.6
Infertility	2	9	1	0	0	12	0.6
Abscessation	10	1	0	0	0	11	0.6
Laryngeal chondritis, Laryngitis	4	7	0	0	0	11	0.6
Poor recovery after surgery	11	0	0	0	0	11	0.6
Pyelonephritis	11	0	0	0	0	11	0.6
Spinal abscess or trauma	3	8	0	0	0	11	0.6
Cataracts	9	1	0	0	0	10	0.5
Abomasal ulceration	7	0	1	1	0	9	0.5
Ascites, Oedema	8	1	0	0	0	9	0.5
Mucosal disease	9	0	0	0	0	9	0.5
Trauma	6	3	0	0	0	9	0.5
Chondrodystrophia	8	0	0	0	0	8	0.4
Diagnosis not reached (Respiratory system)	5	3	0	0	0	8	0.4
Hernias - Scrotal	1	1	6	0	0	8	0.4
Listeriosis	5	3	0	0	0	8	0.4
Milk yield drop	8	0	0	0	0	8	0.4
Anorexia	5	2	0	0	0	7	0.4
Gastrointestinal parasitism	1	3	0	0	3	7	0.4
IBR	7	0	0	0	0	7	0.4
Blindness	3	3	0	0	0	6	0.3
Border Disease	0	6	0	0	0	6	0.3
Diagnosis not reached (Systemic disease)	3	3	0	0	0	6	0.3
Pica, Tail biting	0	0	6	0	0	6	0.3
Poisioning - Bracken	1	5	0	0	0	6	0.3
Udder abnormalities	1	5	0	0	0	6	0.3
Hip luxation	4	1	0	0	0	5	0.3
Neoplasia	5	0	0	0	0	5	0.3
Nephritis	5	0	0	0	0	5	0.3
Pain	5	0	0	0	0	5	0.3
Testicular abnormalities	0	5	0	0	0	5	0.3
Abortion	2	2	0	0	0	4	0.2
Actinomycosis (Lumpy jaw)	4	0	0	0	0	4	0.2

Referral Reason	Cattle	Sheep	Pigs	Alpacas	Goats	Total	Total %
Cerebellar lesions	4	0	0	0	0	4	0.2
Diagnosis not reached (Skin disease)	3	1	0	0	0	4	0.2
Femoral nerve paralysis	4	0	0	0	0	4	0.2
Footrot	1	3	0	0	0	4	0.2
Liver abscesses	4	0	0	0	0	4	0.2
Omphalitis	4	0	0	0	0	4	0.2
Sudden death	3	1	0	0	0	4	0.2
Swellings, lumps or masses	3	1	0	0	0	4	0.2
Actinobacillosis (Wooden tongue)	3	0	0	0	0	3	0.2
Anaemia	1	2	0	0	0	3	0.2
Atresia ani	3	0	0	0	0	3	0.2
Caecal dilation	3	0	0	0	0	3	0.2
Cerebrocortical necrosis	0	3	0	0	0	3	0.2
Corneal ulceration	0	2	0	1	0	3	0.2
Enteritis	3	0	0	0	0	3	0.2
Freemartinism	3	0	0	0	0	3	0.2
Gangliosis	0	3	0	0	0	3	0.2
Infectious keratoconjunctivitis (Pink eye)	1	2	0	0	0	3	0.2
Lungworm	2	1	0	0	0	3	0.2
Mediastinal mass	2	1	0	0	0	3	0.2
Mesenteric or intestinal torsion	3	0	0	0	0	3	0.2
Phlebitis	3	0	0	0	0	3	0.2
Photosensitisation	2	1	0	0	0	3	0.2
Renal amyloidosis	3	0	0	0	0	3	0.2
Salmonellosis	3	0	0	0	0	3	0.2
Sinusitis	3	0	0	0	0	3	0.2
Urinary abnormalities, infection	3	0	0	0	0	3	0.2
Uterine torsion	3	0	0	0	0	3	0.2
Vagal indigestion	3	0	0	0	0	3	0.2
Ventricular septal defect	3	0	0	0	0	3	0.2
Abdominal mass	2	0	0	0	0	2	0.1
Baldness	2	0	0	0	0	2	0.1
BVD	2	0	0	0	0	2	0.1

Referral Reason	Cattle	Sheep	Pigs	Alpacas	Goats	Total	Total %
Closantel toxicity	0	2	0	0	0	2	0.1
CNS lesion	1	1	0	0	0	2	0.1
Coccidiosis	2	0	0	0	0	2	0.1
Copper deficiency (Swayback)	0	2	0	0	0	2	0.1
Depressed animal	2	0	0	0	0	2	0.1
Drenching gun or bolus injuries	1	1	0	0	0	2	0.1
Emphysema	2	0	0	0	0	2	0.1
Facial nerve deficits	2	0	0	0	0	2	0.1
Fibrosed udder	0	2	0	0	0	2	0.1
Fistula	2	0	0	0	0	2	0.1
Hermaphrodite	0	2	0	0	0	2	0.1
Hydrocephalus	2	0	0	0	0	2	0.1
Jaundice	1	1	0	0	0	2	0.1
Liver failure	2	0	0	0	0	2	0.1
Nystagmus	2	0	0	0	0	2	0.1
Ocular abnormalities	1	1	0	0	0	2	0.1
Oral ulceration	2	0	0	0	0	2	0.1
Osteomyelitis	0	2	0	0	0	2	0.1
Papillomatosis	2	0	0	0	0	2	0.1
Persistent urachus	2	0	0	0	0	2	0.1
Poisioning	2	0	0	0	0	2	0.1
Pyrexia	2	0	0	0	0	2	0.1
Regurgitation	1	0	1	0	0	2	0.1
Retained foetal membranes	2	0	0	0	0	2	0.1
Robotic gait, Kangaroo gait	1	1	0	0	0	2	0.1
Ruminal acidosis	2	0	0	0	0	2	0.1
Ruminal stasis	2	0	0	0	0	2	0.1
Sole ulcer	2	0	0	0	0	2	0.1
Swayback	0	2	0	0	0	2	0.1
Umbilical abscess	2	0	0	0	0	2	0.1
Urethral rupture	2	0	0	0	0	2	0.1
Urolithiasis	2	0	0	0	0	2	0.1
URT abnormalites	1	1	0	0	0	2	0.1
Vaginal discharge or bleeding	2	0	0	0	0	2	0.1

Referral Reason	Cattle	Sheep	Pigs	Alpacas	Goats	Total	Total %
Vein distension	2	0	0	0	0	2	0.1
Wobbler syndrome	0	2	0	0	0	2	0.1
Brisket mass	1	0	0	0	0	1	0.1
Clostridial enterotoxaemia	0	0	0	0	1	1	0.1
Constipation	1	0	0	0	0	1	0.1
Digital dermatitis	1	0	0	0	0	1	0.1
Dropping cud	0	1	0	0	0	1	0.1
Epistaxis	1	0	0	0	0	1	0.1
Fatty liver	1	0	0	0	0	1	0.1
Flaccid paralysis	0	1	0	0	0	1	0.1
Foot granuloma	0	1	0	0	0	1	0.1
Foreign body	0	1	0	0	0	1	0.1
Haematoma	1	0	0	0	0	1	0.1
Hemiparesis	1	0	0	0	0	1	0.1
Hernias	0	0	1	0	0	1	0.1
Hernias - Perineal	1	0	0	0	0	1	0.1
Hypersalivation	1	0	0	0	0	1	0.1
Interdigital dermatitis	0	1	0	0	0	1	0.1
Leptospirosis	1	0	0	0	0	1	0.1
Luxation	0	1	0	0	0	1	0.1
Macerated foetus	1	0	0	0	0	1	0.1
Melena	0	1	0	0	0	1	0.1
Meningitis, Encephalitis	1	0	0	0	0	1	0.1
Muscular atrophy	1	0	0	0	0	1	0.1
Nephrosclerosis	1	0	0	0	0	1	0.1
Nerve paralysis	1	0	0	0	0	1	0.1
Opistothonos	1	0	0	0	0	1	0.1
Orchitis	0	1	0	0	0	1	0.1
ORF	0	1	0	0	0	1	0.1
Osteochondritis dissecans	1	0	0	0	0	1	0.1
Otitis	0	0	1	0	0	1	0.1
Paraparesis	1	0	0	0	0	1	0.1
Plantigrade gait	1	0	0	0	0	1	0.1
Poisioning - Acorn/Oak	1	0	0	0	0	1	0.1

Referral Reason	Cattle	Sheep	Pigs	Alpacas	Goats	Total	Total %
Poisioning - Ragwort	1	0	0	0	0	1	0.1
Polymelia	1	0	0	0	0	1	0.1
Prolapsed nictitating membrane	1	0	0	0	0	1	0.1
Protein-calorie malnutrition, Inappropriate diet	0	1	0	0	0	1	0.1
Protoporphyria	1	0	0	0	0	1	0.1
Pyoderma	1	0	0	0	0	1	0.1
Rectal or Anal stricture	0	0	1	0	0	1	0.1
Renal abscessation	1	0	0	0	0	1	0.1
Ringworm	1	0	0	0	0	1	0.1
Rumen fluke	1	0	0	0	0	1	0.1
Scoliosis / Kyphosis	1	0	0	0	0	1	0.1
Seizures	1	0	0	0	0	1	0.1
Septicaemia	1	0	0	0	0	1	0.1
Seroma	1	0	0	0	0	1	0.1
Skin disease	0	0	0	1	0	1	0.1
Stiffness	1	0	0	0	0	1	0.1
Stillbirth	0	1	0	0	0	1	0.1
Tendon abnormality	1	0	0	0	0	1	0.1
Tetanus	1	0	0	0	0	1	0.1
Vaginal prolapse	1	0	0	0	0	1	0.1
Vaginal tear	1	0	0	0	0	1	0.1
Varicocele	0	1	0	0	0	1	0.1
White muscle disease	0	0	0	1	0	1	0.1
Total	**1,270**	**588**	**80**	**4**	**4**	**1,946**	**100**

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